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THE DISCONFORMITY BETWEEN THE BEDFORD AND BEREA FORMATIONS IN CENTRAL OHIO[1]

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INTRODUCTION

Most of the exposures of disconformity between the Bedford and Berea formations in central Ohio, described in this paper, have been known to the writer for the last eight years. A halftone of one of these outcrops showing the irregular base of the Berea sandstone and the subjacent Bedford shale was published in December, 1904, in the *American Geologist*.[2] Lantern slides of this and other localities, showing similar structure made from photographs taken by the writer and his assistants, are in the collection of the Department of Geology of Ohio State University and have been available

[1] Published by permission of the State Geologist of Ohio.

[2] *American Geologist*, XXXIV, Pl. XIX, Fig. 6, showing contact of Berea sandstone and Bedford shale on bank of Smith Run.

for use by the various teachers during the last five or six years. The writer has used them in his lectures to a succession of classes, while a large number of students have visited one or more of the localities on field trips.

A similar disconformity was found between these formations in northern Ohio and an account of its occurrence at various localities from southwest of Cleveland eastward is contained in *Bulletin No. 15* of the Geological Survey of Ohio now passing through the press. A part of the evidence showing such a disconformity in northern and central Ohio was presented by the writer in a paper entitled the "Contact of the Bedford and Berea Formations in Ohio" at the Ohio Academy of Science meeting in Columbus on December 1, 1911. The part of that paper describing the disconformity in central Ohio makes the following portion of this article. On the day that the writer read this paper he received the October-November, 1911, number of the *Journal of Geology* containing an article by Mr. Wilbur G. Burroughs describing the unconformity between these two formations near South Amherst, Lorain County, in northern Ohio.[1]

Definition of disconformity.—The stratigraphic term disconformity is used in this article as defined by Dr. Grabau "to cover unconformable relation of strata where no discordance of dip exists,"[2] a term that was proposed by him in 1905.[3] For this type of unconformity, which has generally been called unconformity by erosion, Professor Crosby has recently proposed the name *para-unconformity*.[4]

DESCRIPTION OF SECTIONS

In this article only a few of the most interesting outcrops showing the contact of the Bedford and Berea formations on the Westerville and East Columbus quadrangles in central Ohio will be described.

Spruce Run sections.—An excellent contact occurs on the north branch of Spruce Run on the Frank E. Hoover farm, 2¼ miles

[1] *Journal of Geology*, XIX, 655–59.

[2] *Science*, N.S., XXIX (May 7, 1909), 750.

[3] *Ibid.*, XXII (October 27, 1905), 534.

[4] *Journal of Geology*, XX (1912), 296.

southeast of Galena and 6½ miles northeast of Westerville. The contact is finely shown for some rods on the northern bank of the stream where the following section was measured:

SECTION ON NORTH BRANCH OF SPRUCE RUN

No.	Thickness Feet	Total Thickness Feet
5. *Berea sandstone.*—Top of bank. Buff sandstone containing numerous brown spots and composed of rather small grains of quartz sand as seen under lens. The base of the layer somewhat irregular with a tendency to concretionary structure.....	3⅔ ±	11 ±
4. Zone composed mostly of thin sandstone to arenaceous shale; but with the texture of the Berea. There is, however, a little soft, buff shale. The zone varies in thickness from 7 in. to 1 ft. 4 in.....	1 ±	7¼ ±
3. Buff, quartz sandstone containing many brown spots as weathered. The top of this zone is even; but the base is irregular, making a variation in thickness from 1 ft. 5 in. to 2 ft. 10 in. The under side of this sandstone is irregular and rough as though conforming in shape to the uneven upper surface of the Bedford. The lower part, at least, of this zone is contorted as by concretionary action, so that it has the appearance of a concretionary layer. The disconformity is shown in Fig. 1 of this bank.....	2 ±	6¼ ±
2. *Bedford formation.*—Bank composed mainly of soft, blue to buff, argillaceous shale with occasional thin layers of sandstone varying from ½ to 1½ in. in thickness. The top of this shale is irregular as though worn by erosion; but in places the thin layers are depressed where the base of the concretionary-like superjacent layer is lowest as though pushed downward by the concretionary action. The thickness of this zone from water level to the base of the concretionary layer varies from 5 ft. 3 in. to 7 ft. 2 in....	6¼ ±	6¼ ±
1. Farther down the stream and stratigraphically lower than the above zone in the midst of blue, argillaceous shales are blue, hard, compact sandstones, some of them several inches in thickness, which weather to brown, rotten stone indicating the presence of $CaCO_3$.		

A view of this bank is shown in Fig. 1, in which the strips of paper and the hammer indicate the undulating contact of the Bedford and

Berea formations. Above the basal, concretionary sandstone of the Berea, zone No. 3, is the zone of thin sandstone to arenaceous shale, No. 4, above which is the continuous sandstone of zone No. 5, with some concretionary structure in the lower part.

The contact of the Bedford and Berea formations is excellently shown on both banks of the south branch of Spruce Run, one mile

FIG. 1.—Bank on north branch of Spruce Run showing the undulating contact of the Bedford and Berea formations as indicated by the strips of paper and the hammer. Photograph by T. M. Hills.

south of the place just described on the north branch. These banks are not far below the highway on the farm owned by Mr. Frank Merrit of Delaware, now occupied by A. Looker, and about 6 miles northeast of Westerville. The southern bank shows more of the upper part of the Bedford and the following section was measured near its eastern end:

SECTION ON SOUTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.		Thickness Feet	Total Thickness Feet
10.	*Berea sandstone.*—Old quarry near the top of the bank which contains layers of buff, fine-grained, quartz sandstone with numerous brown spots when weathered. Some of them are not very hard and weather to a decided brown color. Certain ones		

No.		Thickness Feet	Total Thickness Feet
	have a thickness of 11 in. and some are also ripple-marked. Rather more than 8 ft. of these layers are shown in the wall of the old quarry.....	8+	40½
9.	Buff, rather fine, quartz-grained sandstone, the layers generally varying from 3 to 10 in. in thickness; but some of them are rather thin or even shaly. It contains grains of marcasite and on weathering shows numerous brown spots.....	13½	32½
8.	Thin-bedded to shaly, buff sandstone.....	1¼	19+
7.	Sandy, buff shale.....	2 7/12	17⅝
6.	Very fine, quartz-grained, buff sandstone zone, the lower part of which at the eastern end is somewhat contorted, apparently from concretionary action. On weathered surface this sandstone is not dark brown and rotten like the lower sandstones on this bank. The bottom of this sandstone is irregular, conforming to the irregularities in the surface of the underlying shale. This zone is considered the base of the Berea formation and is separated by a line of disconformity from the underlying shale...	1¾±	15¼
5.	*Bedford formation.*—Blue, soft, argillaceous shale the upper surface of which is uneven, the zone varying in thickness from 2 to 6 in.....	⅓±	13½
4.	Layer of calcareous, blue, very hard, compact sandstone which weathers to a brown color, and the rock becomes rotten. The layer varies from 4 to 5 in. in thickness. It contains 8½ per cent of $CaCO_3$, and $MgCO_3$, which gives it a marked chemical difference from that of the superjacent Berea sandstone.....	½+	13⅛+
3.	Mainly blue, soft, argillaceous shale; but with an occasional thin, bluish (brownish as weathered) sandstone layer varying from ½ to 1½ in. in thickness	3⅝	12⅝
2.	Blue, very hard, compact, calcareous sandstone, weathering to a dark-brown color and becoming rotten. It tends to split into two layers and varies in thickness from 1 ft. 9 in. to 2 ft. It is strongly calcareous, containing 26.35 per cent of $CaCO_3$ and $MgCO_3$.....	1⅛+	9
1.	Blue, arenaceous and argillaceous shale alternating with layers of blue, hard, compact, calcareous sandstone, varying from 1 to 6½ in. in thickness and some of them ripple-marked. Stream level.....	7⅛	7⅛

In the above section there is a very marked difference in the percentage of calcium and magnesium carbonates in the sandstones which are referred to the Bedford and Berea formations. The following table gives the analysis by Professor D. J. Demorest, of Ohio State University, of samples from zones 2, 4, and 6 of the above section.

	Zone No. 2 (1¼ to 2 ft. Sandstone, 4 to 5 ft. below Zone 6)	Zone No. 4 (4 to 5 in. Sandstone, 2 to 6 in. below Zone 6)	Zone No. 6 (Base of Berea)
	Per cent	Per cent	Per cent
$CaCO_3$	18.75	6.50	0.25
$MgCO_3$	7.60	2.00	0.00
Fe_2O_3	4.00	2.90	1.00
Quartz	52.80	59.10	76.00
Feldspar	4.40	9.30	8.00
Clay	8.40	20.60	14.50

An examination of the above table at once shows the high percentage of calcium and magnesium carbonates in the sandstones of zones Nos. 2 and 4, which are included in the Bedford, and the very small amount, only ¼ of 1 per cent, in the basal sandstone of the Berea. The sandstone layer almost at the very top of the Bedford, only from 2 to 6 in. below the base of the Berea or zone No. 6, contains 6½ per cent of $CaCO_3$ and 2 per cent of $MgCO_3$, or a total of 8½ per cent of these carbonates as against the ¼ of 1 per cent of $CaCO_3$ in the basal sandstone of the Berea. While in the thicker Bedford sandstone, zone No. 2, between 4 and 5 ft. below the base of the Berea the proportion is still more marked, since it contains 18.75 per cent of $CaCO_3$ and 7.60 per cent of $MgCO_3$, or a total of 26.35 per cent of these carbonates. This shows that more than one-fourth of the entire composition of this sandstone is composed of the calcium and magnesium carbonates, which clearly explains why this stone becomes rotten on weathering and the basal Berea with only ¼ of 1 per cent of $CaCO_3$ does not. Again, there is a marked increase in the amount of quartz in passing upward from the Bedford into the Berea, which is 52.80 per cent in zone No. 2, 59.10 per cent in zone No. 4 almost at the top of the Bedford, and 76 per cent in zone No. 6 at the base of the Berea. The percentage of quartz is almost 17 per cent greater in the basal sandstone of the

Berea than in the top one of the Bedford from 2 to 6 in. lower. This marked change in the chemical composition of the sandstones above and below the line of disconformity, together with that structure, is considered as proving that the line of separation between the Bedford and Berea formations occurs at the horizon of this line of disconformity.

The lower part of the above section is shown in Fig. 2. The hammer with the sheet of paper rests on top of the calcareous sand-

FIG. 2.—Southern bank on south branch of Spruce Run showing contact of Bedford and Berea formations. The hammer and sheet of paper mark the 1¾- to 2-ft. layer of calcareous sandstone in the Bedford and just above the sheet of paper in the man's hand is the base of the Berea. Photograph by T. M. Hills.

stone, zone No. 2, the upper calcareous sandstone near the top of the Bedford, zone No. 4, is just under the sheet of paper in the man's hand and above it is the basal, concretionary sandstone of the Berea, zone No. 6. Above the basal sandstone in ascending order may be seen the shale of zone No. 7, the thin-bedded to shaly sandstones of No. 8, and the lower layers of the continuous sandstones of No. 9.

On the northern bank, a few rods farther up the stream, is another interesting outcrop, showing the contact of the two formations, only

not so much of the upper part of the Bedford is exposed as on the southern bank.

UPPER SECTION ON NORTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.	Thickness Feet	Total Thickness Feet
6. *Berea sandstone.*—Old quarries on upper part of bank containing buff-colored, rather fine-grained, quartz sandstone. Lower part of zone partly covered; but apparently continuous sandstone layers of moderate thickness	25¼	38¼
5. Zone composed in the upper part mainly of arenaceous, blocky shale and in the lower part of contorted, buff, fine-grained, quartz sandstone. The contorted or concretionary sandstone in general varies in thickness from 0 up to 3 ft. 3 in. and even to the entire thickness of the zone. The concretionary or contorted sandstone also occurs at different levels in the shale zone. At two places the concretionary sandstone extends from the top of the Bedford shale clear up to the base of the apparently continuous sandstones, in other words, occupies the full width of this zone. Again a little above the lower end of the bank the concretionary sandstone fails altogether and the rather blocky, arenaceous shales extend from the top of the Bedford up to the base of the continuous sandstone with a thickness of 6½ ft. There is a lithologic difference, however, between the Bedford and Berea shales on this bank, the Berea containing fine grains of quartz sand. The base of this zone is considered the base of the Berea which is separated by a line of disconformity from the subjacent Bedford	6½	13
4. *Bedford formation.*—Zone composed mainly of blue, soft, argillaceous shale with an occasional thin, arenaceous lamina. The upper surface is uneven; but near the lower end of the bank the zone is 11 in. thick	11/12	6½–
3. Blue, very hard, compact, calcareous sandstone, weathering to a dark-brown color and becoming rotten, varying from 3 to 3¾ in. in thickness. This sandstone corresponds to zone No. 4 of the section on the southern bank, where it is from 4 to 5 in. thick; but with only from 2 to 6 in. of shale between it and the base of the Berea	¼	5½+

No.	Thickness Feet	Total Thickness Feet
2. Blue, arenaceous and argillaceous shales with thin layers of blue, hard, compact sandstone from 1½ to 2 in. thick. Several of the thin sandstone layers are ripple-marked. This zone is 3 ft. 10½ in. thick and corresponds to No. 3 of the section on the southern side, which is 3 ft. 10 in. thick	3⅝+	5¼+
1. Blue, very hard, compact, calcareous sandstone, weathering to a dark brown and becoming rotten. It splits into two layers and 1 ft. 5 in. is shown to water level at the lower end of the bank. Ripple-marks occur. This zone corresponds to No. 2 on the other side of the run, where it is from 1¾ to 2 ft. thick. Stream level	1 1⅝	1 1⅝

Farther down the stream on the northern side is a considerably higher bank which was measured by Mr. Eugene Schmidt.

LOWER SECTION ON NORTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.	Thickness Feet	Total Thickness Feet
7. *Berea sandstone.*—Buff sandstones, the layers of various thickness	7¼	36¾
6. Rather massive, buff sandstone, the lower part with contorted or concretionary structure and the upper part with thinner layers	2	29½
5. Shale zone with some sandstone, 1½ ft. thick; but in some places apparently thicker	1½	27½
4. Contorted or concretionary, buff sandstone zone with shale in middle. At the place measured 2+ ft. in thickness; but not so thick at all places on the bank. Irregular lower surface, forming the base of the Berea sandstone	2+	26
3. *Bedford formation.*—Blue shale with thin layers of sandstone	3⅓	24+
2. Blue, sandstone zone which on the edge splits into thin layers, with a thickness of 2 ft. or more. This apparently corresponds to zone No. 1 of the section farther up the run and No. 2 of the one on the opposite side of the stream	2±	20¾
1. Blue, argillaceous and arenaceous shales with thin layers of blue sandstone from 1 to 4½ in. thick. Stream level	18¾	18¾

Rocky Fork section.—This stream enters Big Walnut Creek not far below Gahanna, and various sections on its banks have been more or less fully described by the writer in former papers.[1] There has been some uncertainty where the line of division between the Bedford and Berea formations should be drawn and in his later papers the base of a concretionary sandstone has been considered as marking this horizon.[2] Later studies appear to support this conclusion and a very brief statement of these additional data will now be given. In former papers a section at the lower end of the gorge, where the basal part of the Berea is shown, and another one farther up the creek on the opposite and eastern bank, where the entire Berea formation occurs, have generally been described. On the western side of the stream, between the two cliffs mentioned above, is another one which will now be described.

SECTION ON WESTERN BANK OF ROCKY FORK

No.	Thickness Feet	Total Thickness Feet
4. *Berea sandstone.*—Buff, quartz sandstone which forms upper part of cliff. Some of the layers are fairly thick; but more of them are thin-bedded....	26	42½
3. Arenaceous shale changing to thin sandstone at top of zone. This shale is more sandy than that in zone No. 1 of the Bedford. The measurements for this zone have varied from 6 ft. 2 in. up to 7 ft. 8 in., depending upon the amount of thin-bedded sandstone at the top which has been included.....	6¾ ±	16½
2. Concretionary sandstone stratum composed largely of rather fine-grained, quartz sand. Varies in thickness from 1 ft. 10 in. to 2+ ft.....	2	9¾
1. *Bedford formation.*—The surface is somewhat irregular, indicating a line of disconformity between the two formations. Mainly blue, argillaceous shale with occasional thin layers of compact, blue, calcareous sandstone, which weather to a brown, rotten stone.....	7¾	7¾

Samples were taken from a thin sandstone a few inches below the top of zone No. 1 and from the lower part of the concretionary

[1] *Journal of Geology*, IX (1901), 216–18; *ibid.*, X (1902), 274–78; *American Geologist*, XXXIV (1904), 340, 341.

[2] *Journal of Geology*, X, 278; *American Geologist*, XXXIV, 340, footnote.

sandstone, zone No. 2, which have been analyzed by Professor D. J. Demorest with the following result:

	Near the Top of Zone No. 1	Base of Zone No. 2 (Concretionary Sandstone)
	Per cent	Per cent
$CaCO_3$	16.5	1.6
$MgCO_3$	3.8	0.0
Fe_2O_3	5.1	2.0
TiO_2	0.2	0.2
Clay	17.4	11.2
Quartz	48.0	70.0
Feldspar	9.0	15.0

In the above analysis it will be seen that the thin sandstone a few inches below the top of zone No. 1 contains 20.3 per cent of calcium and magnesium carbonates, which a few inches higher in the base of the concretionary sandstone (zone No. 2) decrease to 1.6 per cent. On the other hand, the lower sandstone contains only 48 per cent of quartz, which in the base of zone No. 2 has increased to 70 per cent. The chemical composition of these sandstones, separated by only a few inches of shale, is decidedly different and strongly supports drawing the line of separation between the Bedford and Berea formations at the base of the concretionary sandstone as given above, where it had been placed on structural evidence.

The line of division between the Bedford and Berea formations is not so clearly shown on the next cliff on ascending the stream which is on its opposite side. The base of a sandstone layer varying from 4 to 6 in. in thickness, which in some places has concretionary structure and in others is broken and displaced, has formerly been considered the base of the Berea.[1] The concretionary layer of the lower bank is at about the same level as this sandstone as nearly as can be determined by hand level. Eleven to 16 in. below this 4- to 6-in. sandstone is a thinner one which perhaps should also be included in the Berea formation. The section of the lower part of this bank is as follows:

[1] *American Geologist*, XXXIV (1904), 340, footnote, No. 2 of section, and also see Pl. XVIII, Fig. 3, where the student stands on top of this sandstone.

SECTION ON EASTERN BANK OF ROCKY FORK

No.		Thickness Feet	Total Thickness Feet
5.	Gray, fine-grained, quartz sandstone varying in thickness from 4 in. to 1 ft.	$1\frac{8}{12}\pm$	6
4.	Bluish shales which are quite arenaceous and contain some small sandstone concretions. These shales only slightly resemble those of the Bedford	$3\frac{7}{12}$	$5\frac{1}{6}$
3.	Bluish-gray, compact, fine-grained, quartz sandstone, from 4 to 6 in. thick. This layer in places has concretionary structure and again it is broken and displaced. In former section given as the basal one of the Berea formation.[1]	$\frac{5}{12}\pm$	$1\frac{7}{12}$
2.	Blue shales with some thin, sandy layers, the thicker ones ripple-marked. Zone varies from 11 to 16 in. in thickness	$1\pm$	$1\frac{1}{6}$
1.	Compact, blue, fine-grained and thin-bedded sandstone which is ripple-marked and is $1\frac{3}{4}$ in. thick. This is a somewhat calcareous sandstone, as may be seen from the analysis, with a texture somewhat like the Bedford sandstones	$\frac{1}{6}-$	$\frac{1}{6}-$

These three sandstones were analyzed by Professor D. J. Demorest with the following result:

	Zone No. 1	Zone No. 3 (Former Base of Berea)	Zone No. 5
	Per cent	Per cent	Per cent
$CaCO_3$	5.1	1.4	0.8
$MgCO_3$	1.8	0.0	0.0
Fe_2O_3	4.4	2.0	2.0
TiO_2	0.2	0.2	0.2
Clay	18.5	13.4	13.0
Quartz	59.0	66.0	66.0
Feldspar	10.0	17.0	18.0

It will be seen from the above analysis that the calcium and magnesium carbonates (6.9 per cent) of zone No. 1 are lower than in the other analyses of Bedford sandstones of this region, while the amount of quartz is not greater than in some of them. In the two higher sandstones the amount of $CaCO_3$ diminishes from 1.4 per cent to 0.8 per cent, while there is no $MgCO_3$ and the quartz has

[1] *American Geologist*, XXXIV (1904), 340, footnote, No. 2 of section.

increased to 66 per cent in each sandstone. It is to be noted that the amount of feldspar in the two upper sandstones is 17 and 18 per cent respectively, so that they may be termed arkose sandstones. These analyses apparently favor drawing the line of division between the Bedford and Berea formations at the same horizon, viz., the base of zone No. 3, as in the former section of this bank. Although the chemical change is not striking, still there is a marked decrease in the carbonates of the sandstones of zones Nos. 3 and 5 as compared with zone No. 1, while the upper sandstones have a larger percentage of quartz than the lowest one.

Smith Run section.—In the northwestern corner of Fairfield County, 1¼ miles southwest of Lithopolis and about 4 miles south of Canal Winchester, is an interesting section on Smith Run, an eastern tributary of Big Run. Smith Run is about opposite the Nancy Cole house.

SECTION ON SMITH RUN

No.	Thickness Feet	Total Thickness Feet
6. *Cuyahoga formation.*—Blue, fine-grained sandstones alternating with shales, some of the sandstone layers a foot or more in thickness	23⅔	83
5. Two layers of fine-grained sandstone which are conspicuous on the southern bank	4½	59½
4. Bluish to light-gray, argillaceous shale which varies in thickness from 5½ to 6½ ft. Two ft. 4 in. below the top of the shale is a 3½-in. layer of sandstone	6±	55
3. *Sunbury shale.*—Thin, tough, even-layered black shale which is well shown in the narrow part of the glen. The measurements vary from 20⅔ ft. to 26⅔ ft. Specimens of *Lingula melie* Hall, *Orbiculoidea newberryi* (Hall) Herrick and fish scales occur about 3½ in. above its base and again abundantly at a horizon 4 ft. 8 in. above the base, near the top of the shale bank overlying the last outcrop of the Berea in going up stream	20⅔+	49
2. *Berea grit.*—Rather coarse-grained, quartz sandstone which on the weathered surface is much stained, rusty, brownish or even blackish. The upper part contains much marcasite, so that the weathered top surface is pitted and rough, while it is much discolored or blackened. The cliff on the eastern side		

No.		Thickness Feet	Total Thickness Feet
	has a zone of marcasite at the base and it appears to be more or less common throughout the entire thickness. In the small gorge where the run cuts through the formation its entire thickness is shown on each side which varies from 1 ft. 11 in. to about 7 ft. 6 in. Its under surface is uneven, apparently corresponding to the inequalities in the upper surface of the underlying shale. The under surface of the Berea as shown on the western bank is decidedly irregular. From the point where the sandstone is lowest its base, or the top of the Bedford as it is followed up stream, rises 3 ft. 10 in. in a horizontal distance of 21 ft. At the lower end of the cliff where the sandstone has been exposed in recent years by a landslide the base of the Berea rises rapidly from its lowest point to a height of 5 ft. 8 in. and the sandstone is apparently reduced to a thickness of 1 ft. 11 in. In the small gully entering this gorge of Smith Run, just above the western cliff, the Berea is only 2 ft. 7 in. thick; while about 36 ft. farther west on the eastern bank of Smith Run it is about 7½ ft. thick. In all these outcrops it is the lower part of the Berea which thins and thickens, since the upper surface apparently remains uniform with the black Sunbury shale generally shown resting on it. There is no tendency to concretionary structure in the Berea sandstone at this locality and there is obviously a line of disconformity between the Berea and Bedford formations	$6\frac{1}{2}\pm$	$28\frac{1}{2}$
1.	*Bedford shale.*—Soft, argillaceous, bluish-gray to gray shale on bank beneath the Berea sandstone. Farther down the run is chocolate, argillaceous shale which becomes mottled in color toward its mouth. The thickness varies from 22 to 27 ft., depending upon whether it is measured to the lowest or highest point of the under surface of the Berea. Water level of Big Run	22	22

An earlier account of this section was published in the *American Geologist*,[1] together with a halftone of the western bank on which

[1] XXXIV (December, 1904), 344, 345.

the disconformity in the contact of the Bedford and Berea formations is finely shown.[1]

A view of the lowest outcrop of the Berea sandstone, as described in the above section, is given in Fig. 3. The student is indicating the lowest point, stratigraphically, of the base of the Berea which is seen to gradually rise as followed up stream. Below the sandstone is the soft, gray Bedford shale. At the line of the prominent joint in the Berea, a little farther down stream than the student, the base

FIG. 3.—Disconformable contact of the Bedford and Berea formations on Smith's Run. Photograph by H. A. Gleason.

of the Berea rises rather abruptly, so that it is 5 ft. 8 in. higher than its lowest point. The base of this part of the Berea is clearly shown at the left edge of the picture. The top surface of the Berea is uniform all along this bank, showing that there has not been any settling of the blocks along the joint line.

Slate Run section.—About $3\frac{1}{2}$ miles southwest of Lithopolis or three-fourths of a mile northwest of Marcy on the farms of J. M. Hensel and Enos Zwayer in the northeastern corner of Pickaway County, an interesting section is shown along Slate Run.

[1] *Ibid.*, Plate XIX, Fig. 6.

SECTION ON SLATE RUN

No.		Thickness Feet	Total Thickness Feet
5.	*Cuyahoga formation.*—Blue, fine-grained sandstones and some layers of soft, gray shale which contain but little grit. Thin-bedded sandstones with shales and shaly sandstones occur at the base, above which are shales containing concretions	25+	69+
4.	Gray, argillaceous shale which is very soft and gritless, with the exception of a 6-in. compact, gray sandstone, the base of which is 3 ft. 2 in. above the bottom of this zone	8⅔	44+
3.	*Sunbury shale.*—Thin, black, tough, laminated shale. The sharp contact of this shale with the superjacent, gray, Cuyahoga shale is finely shown in the bed of the run as well as the basal contact at the fall farther down stream with the subjacent Berea. The basal layer of this shale is arenaceous, strongly pyritiferous, and it contains numerous specimens of *Lingula melie* Hall. Different measurements of the thickness of this formation vary from 24⅔ to 26 ft.	26	35½
2.	*Berea sandstone.*—Composed principally of white, quartz sand of moderate coarseness, and forms a single stratum which varies in thickness from a little more than 1 ft. to 5 ft. The upper part contains plenty of marcasite and the weathered surface is pitted from its disintegration; but the surface is horizontal, not undulating. The lower surface is uneven and rough, with ridges which correspond to the thin sandstones in the underlying Bedford, while their faces represent the edges of the layers of soft shale, a character that at this locality Professor Thomas M. Hills first called to my attention. The rapid change in the thickness of this formation and the details of its contact with the Bedford formation are given more fully in the two following more detailed sections at this locality. There is no appearance of concretionary structure in the basal part of the Berea and there is a marked line of disconformity between the Berea and Bedford formations	5±	9½
1.	*Bedford formation.*—Mainly bluish, argillaceous shale with an occasional layer of thin sandstone from ¼ to 1 in. thick. At lower end of cliff with overlying Berea sandstone 4 ft. 7 in. to water level	4½	4½

Farther down the run are outcrops of the chocolate-colored, argillaceous, Bedford shales. Below these are excellent ones of the black Ohio shale, which in places form banks from 30 to 40 ft. in height. An earlier description of this section was given in the *American Geologist*.[1]

The least thickness of the Berea sandstone noted on this run occurs in the small fall on the Enos Zwayer farm, where the following section was measured at the fall's northern angle:

SECTION OF FALL ON SLATE RUN

No.		Thickness Inches	Total Thickness Feet, Inches
3.	*Sunbury shale.*—Basal portion of black, tough shale, the lower layers of which are rather arenaceous, pyritiferous, and tough; but containing near the base specimens of *Lingula melie* Hall and *Orbiculoidea newberryi* (Hall) Herrick	7	2 7
2.	*Berea sandstone.*—Upper part not massive and containing much marcasite or iron pyrite. The sandstone in general is composed principally of white, quartz sand of moderate coarseness. The lower surface is rough, conforming closely to the inequalities in the upper surface of the underlying Bedford. At this point the Berea is thinnest and on the southern bank near that angle of the fall it is 2 ft. to 25 in. thick. This difference in thickness of the Berea is at the expense of the upper part of Bedford, since the upper surface of the Berea is even and regular with a dip up stream upon which the Sunbury black shale rests uniformly. Evident line of disconformity at the base	13½	2
1.	*Bedford formation.*—Bluish, argillaceous shale with an occasional, sandy layer, approximately ¼ in. thick. Level of stream	10½	10½

A view of this angle of the fall is shown in Fig. 4, in which the lower hammer marks the disconformable contact of the Bedford and Berea formations, and the upper one the conformable contact of the Berea and Sunbury shale. The entire thickness of the Berea sandstone is shown, which is only 13½ in. at the corner or angle. It also clearly shows the thickening of the lower part of the Berea on the

[1] XXXIV (December, 1904), 346–48.

FIG. 4.—Fall on Slate Run showing entire thickness of Berea sandstone with Sunbury shale above and Bedford shale below. Each contact indicated by a hammer. Photograph by W. C. Morse.

FIG. 5.—Entire thickness of Berea sandstone, with Sunbury shale above and Bedford shale below, on northern bank of Slate Run. Upper contact indicated by hammer. Photograph by C. S. Prosser.

northern bank as followed down stream, with the consequent decrease in thickness of the upper part of the Bedford.

On the northern bank, 6 ft. farther down stream than the angle shown in Fig. 4, the Berea has thickened from 13½ in. to 2 ft. and its base is stratigraphically lower than in the angle of the fall and cuts off some of the upper part of the Bedford. This is clearly shown by some of the thin sandstone layers, about ¼ in. thick, in the very upper part of the Bedford at the angle of the fall, which are cut off by the base of the Berea as it is followed down stream. Fifteen feet farther down stream from the point where the Berea is 2 ft. thick, it has increased in thickness to 2 ft. 4 in. Twenty feet farther down the run, nearly under the tree, the Berea has decreased from 2 ft. 4 in. to 15 in., and the upper part of the Bedford increased accordingly. This bank is shown in Fig. 5 where the hammer marks the contact of the Sunbury shale and Berea sandstone, below which the upper part of the Bedford shale is shown. At the fence 70 ft. farther down the stream and still on the same side, the Berea has thickened to about 5 ft. It again thins as followed down stream and 20 ft. below the fence at the lower end of the cliff it is only about 1 ft. 8 in. thick. In all this interval the upper surface of the Berea remains about uniform and the differences in thickness are due entirely to changes in its basal portion. The following section was measured at the lower end of the cliff farthest down stream:

SECTION OF LOWEST CLIFF ON SLATE RUN

No.		Thickness Feet, Inches	Total Thickness Feet, Inches
4.	*Berea sandstone.*—Composition similar to that in the other sections at this locality. It is only about 1 ft. 8 in. thick, but thickens rapidly as followed up stream. The lower surface is irregular and rough, corresponding to inequalities in the upper surface of the Bedford formation. No indication of concretionary structure. Conspicuous line of disconformity between the Berea and Bedford formations	1 8	5 3
3.	*Bedford formation.*—Bluish, argillaceous shale with occasional thin, arenaceous layers which a short distance farther up the bank are cut off by the descending base of the Berea sandstone.....	0 11	4 7

No.		Thickness Feet, Inches		Total Thickness Feet, Inches	
2.	Arenaceous layer to thin sandstone, from $\frac{1}{2}$ to $\frac{3}{4}$ in. thick, which in a horizontal distance of 4 ft. farther up stream is cut off by the base of the Berea. This shows a decrease in thickness of the upper part of the Bedford formation of about a foot in a horizontal distance of 4 ft. This bank is shown in Fig. 6 in which this layer is indicated by the hammer.....	0	1—	3	8
1.	Mainly bluish, soft, argillaceous shale with an occasional thicker and arenaceous layer. Level of water.....	3	7+	3	7+

FIG. 6.—Disconformable contact of the Bedford and Berea formations on Slate Run. The hammer marks the thin Bedford sandstone, No. 2 of the section. Photograph by W. C. Morse.

GLACIATION IN THE TELLURIDE QUADRANGLE, COLORADO

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PART II

VALLEY OF BRIDAL VEIL CREEK

In elevation this valley ranges from 10,300 feet at the point where Bridal Veil Creek falls into the cirquelike head of the San Miguel valley, to a little more than 13,500 feet, the elevation of the highest peaks on its margin. Above 12,000 feet in elevation it is a broad, flat-bottomed basin a mile or more in width, bounded by cliff walls rising for the most part not more than 200 or 300 feet in height. On this broad, flattened bottom a number of small lakes and ponds occur, lying in rock basins.

Throughout the extreme southwestern part, rock ridges and knobs with rounded surface give character to the topography. Some of the ridges are as much as 50 to 75 feet in height; for the most part, however, the relief is not so great. Some of the rounded surfaces show striae; but in the great majority of cases the general rounded surface is either roughened by unequal erosion or is covered with a layer of small angular fragments, which, in the case of the igneous rocks of this region, easily results from change of temperature. The weathering accomplished since the disappearance of the ice has produced enough soil to support a flora which in the summer months gives a more or less pronounced green color to much of the bottom of the basin.

The south-central part of the basin has a series of tributaries draining numerous small lakes, and flowing north of east to the main stream. Each of these tributaries occupies a level respectively higher than the one next in order to the north, producing in the bottom of the valley the appearance of a series of terraces extending in a direction slightly south of west to north of east.

In the south-central and southeastern part of the basin large angular bowlders up to 15 feet in diameter are scattered over an area of half a square mile or more. These bowlders do not appear to be a part of the talus slope which lies just at the base of the precipitous rock wall which bounds the basin, but, from their somewhat uniform distribution and lack of gradation in size as distance from the cliff face increases, seem to be fragments carried to their present position by the ice. Below about 12,000 feet in elevation the main valley is comparatively narrow, and U-shaped in cross-section.

The channel of the stream in places consists of a narrow gorge 10 to 20 feet deep in the bed rock; in other places it occupies the bottom of the U-shaped cross-section, giving no evidence of having lowered its bed appreciably since the withdrawal of the ice. The amount of post-glacial erosion by the stream may, therefore, be stated as 10 to 20 feet, in the most favorable locations.

The valley is in general well cleaned out; *roches moutonnées*, with abundant striae, are found at many points, the striae being in general approximately parallel to the course of the stream. Some striated surfaces are found on the under side of overhanging ledges which project one or two feet from a nearly vertical cliff face. At about 11,000 feet in elevation, near the trail east of the stream, a striated groove occurs in the nearly perpendicular wall of rock forming the side of the valley. At elevation about 10,700 feet, near the stream, and again a little farther southeast at 11,000 feet, near the trail, pot holes were observed. Each is on the north side of a steep, smooth face of rock in place. The location is such as would result if rock in which a perfect pot hole exists were worn off diagonally across the pot hole, leaving on the steep slope only a trace of the top, while the bottom, still complete, remained wholly back of the sloping face.

Bridal Veil basin has the following tributary basins: (*a*) on the east, (1) East basin, (2) Mud Lake basin, and (3) Gray's basin; (*b*) on the west, (1) Jackass basin, and (2) Silver Lake basin.

East basin.—This basin, above 12,300 feet in elevation, has a comparatively flat bottom and contains a lake lying in a rock basin, which has been converted into a reservoir, increasing its size until

it now has a diameter of nearly half a mile. Northeast of the lake the talus slopes come down to the water's edge; on the southwest, steep, bare slopes of rock in place extend beneath the surface of the water. All along the trail leading into the basin, near the stream, *roches moutonnées* occur. The lake is reported to be 400 feet deep 300 yards from the lower margin; no means were at hand by which to verify or disprove the report.

Mud Lake basin.—This basin is somewhat smaller than East basin. It contains a lake about one-fourth of a mile long and half as broad. An island in this lake, as well as the rock in place on the north side for about 75 feet above the water, shows the rounded outlines of *roches moutonnées*, but no distinct grooves or striae were observed above elevation 12,100 feet. At the head of the basin to the southeast are some rounded knobs of rock in place; but at intervals over the surface angular rock fragments up to 12 feet in diameter appear, partly buried in soil which in the summer is covered with low plants. Beyond this area are the bare talus slopes at the foot of the precipitous bounding walls.

Gray's basin.—Gray's basin is still smaller than Mud Lake basin, and the elevation of its floor is also slightly less, being at 11,900 feet and over. Some rounded, projecting knobs of rock in place occur, but much of the bottom of the basin has enough soil to support a scanty growth of vegetation. In the southeast part of the basin a small rock stream lies at the foot of the talus slope.

Jackass basin and Silver Lake basin.—These basins are characterized by the rounded forms of *roches moutonnées*, and talus slopes sufficiently weathered to support a low alpine flora. Silver Lake basin contains a small lake and has bounding walls less high than the other basins of the Bridal Veil system.

The maximum thickness of ice in the main valley of Bridal Veil Creek was probably not less than 1,200 feet; in the tributary basins, from 200 to 400 feet.

DEER TRAIL BASIN

This basin is a small hanging valley lying more than 1,500 feet above the San Miguel River. Owing to its small size, and its elevation which is on an average perhaps 500 feet less than the

basins tributary to Bridal Veil Creek, the action of the ice was less vigorous. It is like other basins, however, in its flattened profile, in its increased width above the point where it joins the main valley, and in its precipitous bounding walls rising above considerable accumulations of talus. The thickness of ice here was probably from 100 to 300 feet.

VALLEY OF BEAR CREEK

This valley is double headed, and ice from both heads and from La Junta basin on the east united to form the Bear Creek Glacier, about four miles in length. The gradient of the valley, especially toward its head, is steep, locally as much as 1,000 feet per mile. The descent is by a series of precipices. Seen from below (lee side), say from the mill of the Nellie Mine, the valley shows little evidence of glaciation; but seen from above (stoss side), the projecting bosses of rock, and the lower slopes of the valley are obviously smoothed and worn; striae parallel with the course of the valley occur at 9,000 feet elevation. The narrow, deep valley below the upper tributaries is in contrast with the wider and more open basins above. The thickness of the ice which occupied this valley was, at the maximum, more than 1,000 feet.

BASIN EAST OF SAN JOAQUIN RIDGE

The westward-facing slope of Wasatch Mountain shows much talus, and the effect of the ice action is not conspicuous. The eastern part of the basin shows rounded domes of rock of the general form of *roches moutonnées*, but their surfaces are covered with broken rock, and positive signs of glaciation are not evident. Farther west, near the San Joaquin ridge, there are distinct signs of glaciation in the form of *roches moutonnées*, and several ponds in rock basins. The eastern face of the San Joaquin ridge indicates that the thickness of the ice here was not less than 300 feet. The serrate crest of the ridge is in striking contrast with the topography below.

LENA BASIN

Both this basin and its counterpart just west of the base of the San Joaquin ridge are glacial cirques. Both show *roches moutonnées*

in their bottoms, and both have steep descents to the valley below. There is much talus at the bases of the surrounding slopes.

VALLEY OF LAKE FORK

The term Lake Fork is sometimes used to designate that part of the tributary of the San Miguel River from the south which lies above the point of junction with Howard Fork; while that part from the mouth of Howard Fork to the San Miguel River is called South Fork. In this paper, however, the terms lower valley of Lake Fork, and upper valley of Lake Fork, are used to designate, respectively, the portion below and the portion above the mouth of Howard Fork.

LOWER VALLEY OF LAKE FORK

Glacial ice coming down Lake Fork to the valley of the San Miguel not only filled the lower valley of Lake Fork, but spread eastward over the edge of the mesa to a distance of a mile or more from the stream, and together with the glacier in the valley of Bilk Creek entirely covered the mesa between Lake Fork and Bilk Creek for a distance of more than three and one-half miles from the San Miguel River.

The surface of the glacial drift on this mesa is highest toward the northern end, being at a maximum more than 200 feet higher than the outcropping bed rock at the mesa's edge; the surface is lowest just west of the mouth of Turkey Creek, where the drift forms but a thin covering. The ice from Lake Fork passed over the mesa at this point into the valley of Bilk Creek, as is shown by glacial striae on bed rock at the west edge of the mesa, bearing N. 17° W. to N. 24° W. Striae on bed rock at the east edge of the mesa, opposite the mouth of Turkey Creek, vary in direction from N. 3° W. to N. 16° E., the direction of a considerable number being, therefore, approximately parallel to the course of Lake Fork.

The drift on the mesa between Lake Fork and Bilk Creek is arranged in the form of ridges. The highest part of the deposit consists of a ridge about half a mile in length, extending in an approximately north-south direction with a very steep western slope. Southward from this, the ridges have a general northeast-southwest trend, changing at the northeast end to a more northerly

direction. Between these ridges the surface of the deposit is uneven, hummocky, and including kettles occupied in part by small ponds. But although the topography is irregular and uneven, yet the longer dimensions of both the kettles and the elevations are in general parallel to the ridges. The material of the drift on this mesa includes a variety of rocks such as are common to the region; striated bowlders occur at numerous points. The ridges trending northeast-southwest are believed to be due primarily to the action of ice which occupied the valley of Lake Fork; that is, they represent successive positions of the edge of the Lake Fork Glacier as it was finally withdrawing from the mesa, and are, therefore, to be classed as recessional moraines. The north-south ridge near the northern end of the mesa, with its steep western slope, indicates that it, too, was deposited by a glacial sheet from the east. Southward from the lowest part of the mesa as referred to above, the topography is uneven, and not marked by distinct ridges except for a prominent medial moraine three-fourths of a mile long extending from the point of junction of the Bilk Creek and Lake Fork glaciers down to an elevation of about 9,400 feet.

East of Lake Fork, between the San Miguel River and Turkey Creek, the surface of the drift is more or less rough or ridged, the dominant trend of these ridges being parallel to the valley of Lake Fork. The most prominent ridge extends from Vance Creek to Turkey Creek near the eastern edge of the drift, reaching an elevation of more than 9,500 feet at its highest point. North of Vance Creek, while the irregularities of the surface of the drift show distinctly linear arrangement, the ridges are neither so prominent nor so persistent as on the mesa west of Lake Fork.

Southward from Turkey Creek on the east side of the valley for more than two and one-half miles, the topography is wholly irregular and confused. The change in arrangement of the drift is partly due to the greater steepness of the slope on which it lies. From the San Miguel valley to Turkey Creek on the east side of Lake Fork, sedimentary rocks outcrop along the east wall of the valley in a precipitous face below the comparatively level drift-covered area above; but south from Turkey Creek, the sedimentary series

has been worn away to a steep, irregular slope, affording lodgment for glacial débris in greater or less amounts, so that the whole eastern side of the valley from the stream to the eastern limit of the drift presents a steep, irregular surface, with but little change in slope at the elevation corresponding to the edge of the mesa farther north. Landsliding within this area has been noted by Cross;[1] such action is clearly responsible, in part, for the irregular, hummocky topography.

On the west side of Lake Fork, the precipitous face of the sedimentary rocks outcropping below the edge of the mesa extends from the valley of the San Miguel River to about one mile south of the mouth of Turkey Creek. From this point southward for about two miles to the precipice formed by the diorite-monzonite intrusion northeast of Sunshine Mountain, the west slope of the valley, like the eastern, is rough, irregular, and steep, but without precipitous outcrops of rock in place. Unlike the eastern side, however, there is much less glacial débris evident, though rounded pebbles and bowlders, some of them striated, occur at frequent intervals.

In cross-section, the valley of Lake Fork changes from a flat-bottomed, U-shaped form below the mouth of Turkey Creek, to a broadly open, V-shaped form two miles below the mouth of Howard Fork. In general, bed rock in the bottom of the valley is covered with rock waste in the form of alluvium, alluvial fans, or morainal deposits. The alluvial fans are numerous, but comparatively small. Distinct morainal deposits occur only at and a little above the mouth of Turkey Creek—a small recessional moraine, and a fragment of a lateral moraine, respectively.

On the right side of the valley, opposite the junction of Howard Fork with the upper valley of Lake Fork, the drift is found in the form of a well-marked ridge 200 to 300 feet higher than at points above or below. This is clearly another instance of the effect of ice crowding up on the side of a valley opposite to the entrance of a tributary glacier.

The maximum thickness of ice in the lower valley of Lake Fork was about 1,200 feet.

[1] *Telluride Folio*, p. 11.

CIRQUE NORTHEAST OF SUNSHINE MOUNTAIN

The only valley on the west side of the lower valley of Lake Fork which was occupied by a tributary glacier was that one heading in the cirque northeast of Sunshine Mountain. This cirque has practically no exposures of bed rock in its bottom, since the shale which constitutes the underlying formation here weathers readily. In the lower part of the cirque, at an elevation of about 11,000 feet, the slope of the bottom averages about 12°; at 11,300 feet, 20° to 25°; back of this are steep slopes of talus, and above the talus the nearly perpendicular walls of the Telluride formation and igneous rock.

VALLEY OF HOWARD FORK

Howard Fork has but two tributaries that were occupied by glaciers in the more recent epoch, viz., Swamp Canyon and Waterfall Creek. On all sides of Swamp Canyon and its tributaries are found the usual abundant talus accumulations and nearly perpendicular bounding walls. At an elevation of about 11,500 feet, both in the main valley and in the tributary valley on the west, the rounded, smoothed outlines of *roches moutonnées* appear. Striated bowlders were found near the western tributary at an elevation of 11,200 feet. In the lower part of its course the valley shows but little outcrop of rock in place. The maximum thickness of ice in Swamp Canyon was probably from 500 to 800 feet.

The valley of Waterfall Creek has numerous *roches moutonnées* above 11,000 feet in elevation, with striae in some places approximately parallel to the direction of the stream. On the west side of the stream just below the last tributary valley, drift with striated bowlders occurs at 10,750 and at 10,900 feet in elevation. Long talus slopes and cliffs with nearly perpendicular faces form the boundary of the well-cleaned-out valley.

The eastern end of the valley of Howard Fork toward Ophir Pass closely resembles Swamp Canyon in its main features. In the bottom near the stream is a narrow, flattened area, containing a few small ponds; higher up, talus is abundant. The rounded points of exposed rock in place in Ophir Pass indicate that glacial ice was continuous from the valley of Howard Fork over the divide to the east.

Except for deposits about the village of Ophir and near the mouth of Swamp Canyon, the valley of Howard Fork contains but little glacial débris; and of the deposits which may properly be classed as heavy drift that on the north side of the stream near Ophir is partially covered by débris derived from the gullies and ravines cut in the steep southward-facing valley slope. This débris at a short distance north of the stream becomes at the surface at least a true alluvial deposit in the form of a series of alluvial fans, confluent at their lateral edges. The most conspicuous of these fans is that upon which the village of Ophir is built. It has a width (east-west) of about three-fourths of a mile, and its apex is about 400 feet above the main stream at the lower part of Staatsburg Gulch.

In the lower part of the valley near Ophir Station and for a short distance to the east, the valley has the U-shape typical of glaciated valleys, rock in place outcrops at numerous points, and both the rock on the bottom and that on the sides of the valley 200 to 300 feet or more above the stream is rounded, polished, and striated. Eastward from Ophir Station, the entire southward-facing slope of the valley affords but little direct evidence of glaciation; it is furrowed with gullies of sharp V-shaped cross-section down to 10,500 or 11,000 feet in elevation; below this elevation the valleys and ridges are not prominent on the slope. The appearance of a more uniform topography in this lower part is aided by the growth of aspen which is present in some places, and by the alluvial fans which extend across the flattened bottom.

Deposits apparently glacial occur three-fourths of a mile northwest of Ophir village at 10,200 and 10,500 feet in elevation, respectively. On the south side of the valley less than half a mile east of Waterfall Creek, glacial débris with striated bowlders occurs up to about 10,350 feet. Again, on the south side of the stream and west of Swamp Canyon, the surface is covered with glacial drift up to about 11,000 feet. In part it lies in irregular hills, in the form of ridges or benches. This drift includes bowlders in variety, some of them well striated.

The thickness of the ice in the lower part of Howard Fork was probably about 1,000 feet.

UPPER VALLEY OF LAKE FORK

The upper valley of Lake Fork drains a valley proportionately much broader than the other glaciated valleys of the region. As a consequence of its greater width, the action of the ice was less vigorous, and much glacial débris remains. At its maximum a glacier as much as 1,000 feet in thickness moved northward from this valley to join that coming from Howard Fork, as shown by

FIG. 5.—Point below small lake at 11,600 to 11,700 feet, four miles southeast of Trout Lake. Glacial ice passed over this point.

glacial striae on rock in place on the east side at 10,000 feet elevation near the Terrible Mine, glacial débris on the same slope 100 to 200 feet higher, and similar deposits on the west side where the edge of the ice crowded up on the north side of the valley of Wilson Creek, at an elevation of 9,800 to 9,900 feet.

That part of the main valley lying above 10,000 feet in elevation is for the most part well cleaned out. Near the main stream, however, considerable soil has accumulated and supports a forest

growth. *Roches moutonnées* occur at many points above 11,000 feet. Near the pass into the valley of Mineral Creek, at an elevation of 11,900 feet, striae on rock in place bear N. 47° W. Some lakes in rock basins occur, the largest being at 11,600 feet (Fig. 5). Near the margin of the valley the usual talus slopes are found, some of which have weathered until they support sufficient vegetation to give the slopes a covering of green; but for the most part

FIG. 6.—Part of the divide between cirque at head of Trout Lake branch of Lake Fork (on the right), and valley of Cascade Creek (on the left). Elevation of gap in lower central part of view, 12,700 feet. The surface of the glacial ice in the two cirques is believed to have been about up to the lower part of the gap.

the débris consists of apparently unweathered fragments. Fig. 6 shows the steep walls of a part of the southern boundary of the valley.

The eastern slope of the valley, including the tributary valleys from Poverty Gulch to the cirque-valley just above the village of San Bernardo, is steep, irregular in topography, and mostly covered with forest. *Roches moutonnées* occur at a few points, as in

Roger Gulch at 11,200 feet elevation, and in Ground Hog Gulch at 10,900 feet. Glacial drift including bowlders in variety, some of them striated, occur at numerous points, among which may be named: (1) Roger Gulch at 10,200, 10,600, and 10,800 feet; (2) Ground Hog Gulch at 10,500 and 11,100 feet; (3) south branch of Ground Hog Gulch at 10,800 and 11,500 feet; (4) Leslie Gulch at 11,000 feet; and (5) Poverty Gulch at 10,300 feet. Striations on bed rock occur on the south side of the stream draining Poverty Gulch at elevation 10,300 feet, bearing S. 73° W. It is therefore clear that glacial ice covered the whole eastern (westward-facing) slope; the irregularity of the topography is, however, in part due to landsliding, as noted by Cross.[1] The landslide here occurred partly before and partly after the more recent epoch of glaciation. Fig. 7 shows a landslide block which came to its present position before the more recent glacial epoch, as shown by the well-cleaned-out, round-bottomed valley head lying to the northeast of it, the steep walls above the talus, and glacial débris a little farther down the valley. It is in general true that the upper ends of the gulches on the slope here described are cirquelike, have well-cleaned-out, comparatively flat bottoms with occasional ponds, and are bounded by rough, nearly perpendicular walls rising above steep slopes of talus. Rock streams occur on the south side of Poverty Gulch at an elevation of 11,000 to 11,500 feet, and again a half a mile farther south on the other side of the ridge at an elevation of 11,500 to 12,000 feet. The broad cirque lying farthest east on the north side of Sheep Mountain has almost its whole surface below the precipitous bounding walls down to 11,500 feet elevation covered with bare talus slopes; below this a part of the surface supports a forest growth, which in turn gives way to a nearly perpendicular rock face southwest of the artificial lake at 10,000 feet elevation.

The slope south of Trout Lake, like that to the east of the lake, is mostly forest-covered but is less irregular in topography. Due south of Trout Lake, at 10,500 and 10,600 feet elevation, drift with striated bowlders occurs, and hummocky topography including occasional kettles continues to 11,000 feet. Striated bowlders also occur at 10,400 feet elevation southeast of Lizard Head Station.

[1] *Telluride Folio*, pp. 10, 11.

On both the east and the west sides of the central valley on the north side of Sheep Mountain is a medial moraine; on the east side the moraine extends from about 11,600 feet to 11,200 feet in elevation, and is for the greater part of the way a sharp ridge from 15 to 50 feet high; on the west side, the medial moraine is shorter and does not continue to be well marked below 11,400 feet. Besides the drift with striated bowlders already mentioned at 10,400 feet

FIG. 7.—Landslide block of Potosi rhyolite, south of east from Trout Lake Looking north from 12,000-foot point one mile west of Pilot Knob. This block came to about its present position before the more recent glacial epoch.

elevation, the cirque northwest of Sheep Mountain contains deposits of bowlders in variety at 10,500 feet elevation west of the stream and at 10,800 feet more than a quarter of a mile farther east. Since the underlying rock here is shale, no *roches moutonnées* occur. Only the upper 500 feet of this valley is free from forests.

No ice entered the valley from the slopes of Black Face Mountain lying on the west. The upper margin of the ice west of Trout

Lake was a little less than 10,000 feet in elevation; the surface of the ice must, therefore, have had a general slope to the northwest of from 250 to 500 feet per mile, and the moraines about Trout Lake are to be considered as recessional, or as ground moraines.

Trout Lake is practically surrounded by moraines. Cross suggests[1] that the lake may be formed by a dam due to landsliding. While it is quite probable that there has been some movement in the material below the lake of the nature of landsliding, it is also true that so far as sections are exposed in the débris below the lake the deposit is shown to be typically glacial, consisting almost entirely of unstratified drift with bowlders in variety, many of them striated; and since the topography is also such as is found in morainal deposits, that is, irregularly disposed hills and ridges, it seems not inappropriate to class the deposit as morainal even though there may have been some readjustment of the materials since the ice withdrew. On the west and south of the lake there are distinct ridges of drift at several points trending in general in a north-south direction; but much of the surface is quite irregular. East of the lake, the moraine belt is narrow, extending to an elevation not more than 100 to 200 feet above the water's edge. To the southeast, morainal hills are found as far as the upper end of the artificial lake at 10,000 feet elevation. Southwest of Trout Lake they are continuous over the divide into the basin of the Dolores River, and extend up to about 10,400 feet. In this direction small kettles occur. Below the lake (to the north), the moraines continue for one-fourth to one-half a mile at nearly the same elevation as at the lower edge of the lake. Below this morainal dam, just north of the abrupt eastward turn of the railroad, the bottom of the valley is about 100 feet lower, some marshy areas occur, and the morainic hillocks are fewer and much smaller.

Just northeast of the village of San Bernardo *roches moutonnées* occur, and a few rods farther north a low recessional moraine extends from the railroad to the east side of the valley. Sections of this moraine exposed along the railroad show some stratified drift near the top and unstratified lower down, with bowlders in variety, some of them striated. The lower part of the valley just

[1] *Telluride Folio*, p. 10.

above the junction with Howard Fork is steep-sided, V-shaped, with outcropping rock on the east, and slopes covered with talus or soil on the west which, in places, supports a growth of aspen. This forest and the fresh accumulations of talus east of San Bernardo Mountain conceal such signs of glaciation as may have been present, except for occasional patches of bowlders, which, from their rounded and subangular forms and the variety of kinds present, are clearly of glacial origin.

The thickness of the ice in the neighborhood of Trout Lake and in the valleys above was probably on an average not more than 300 to 400 feet, with a possible maximum at some points of 800 feet.

VALLEY OF BILK CREEK

The upper part of the valley of Bilk Creek is double headed, with three small tributary cirque-valleys on the eastern side. Except for the small amount of loose material along the stream in the lower part, and the usual talus accumulations near the upper margins, this part of the valley is well cleaned out. Above 11,000 feet in elevation along the stream draining Bilk basin *roches moutonnées* occur at frequent intervals. At 11,200 feet is a small alluvial flat; below this the stream flows in a channel 100 feet deep at some points. At 11,800 feet and at 12,200 feet in Bilk basin, striae on rock in place have a direction approximately parallel to the course of the stream. At 12,000 feet, and at 12,700 feet, lakes or ponds are found in rock basins. Talus is abundant at the sides and heads of Bilk basin, and on the south side at 11,700 to 11,900 feet is a rock stream. From 11,000 to 11,500 feet in elevation the valley of the south branch of the upper part of Bilk Creek has a more gentle gradient and the bottom is in places marshy. Farther up are *roches moutonnées* and the usual boundary of talus slopes and precipitous rock walls. Abundant talus, partly overgrown with vegetation, flattened bottoms, and walls somewhat less precipitous than in typical cirques characterize the three cirque-valleys on the eastern side.

Magpie Gulch and the cirque lying next to the north contain little direct evidence of glaciation; enough, however, is present to make their occupation by ice certain. Within the lower, forest-

covered portion occasional accumulations of rounded and subangular bowlders in variety occur; in the upper portion, each has the flattened bottom and receding sides which distinguish glaciated cirques from the narrow, V-shaped valleys which were unoccupied by ice. At about 11,000 feet in elevation in the cirque north of Magpie Gulch, the topography is of the irregular form which may in part be due to landsliding. Above this, projecting points of rock in place show well-rounded forms, though no typical *roches moutonnées* occur. The usual long talus slopes and almost perpendicular rock walls form the upper boundary of the cirque. Magpie Gulch is quite similar in its general features; it has, however, a greater length, and contains a much greater accumulation of talus.

Below the mouth of the stream draining Magpie Gulch, glacial drift is present over the greater part of the surface of the valley of Bilk Creek and on the edge of the mesas on either side. In the lower part, however, for a mile or more above the junction of Bilk Creek with the San Miguel River, the drift is not conspicuous; for not only are the sides too steep, for the most part, to afford a place for lodgment for débris, but talus slopes at the base of the cliff faces have formed in post-glacial time, so that drift which may have been left on the less steep slopes nearer the stream has since been effectually concealed. Farther upstream the valley is broader and the products of weathering form alluvial cones and fans, especially on the west side of the stream. Beginning at a point about half a mile north of parallel 37° 55′ N., and continuing up the valley for four miles, glacial débris is in general abundant near the stream. At the lowest point in the tract just named, the débris is in the form of terraces on the east side of the stream, consisting of unstratified drift as far as observed, with bowlders in variety, some of which are striated. The terraces distinguished are two in number, their surfaces being 20 feet and 40 feet, respectively, above the stream Half a mile farther upstream, on the west side, stratified drift is exposed 100 to 150 feet above the stream. At elevation 9,000 to 9,100 feet morainal hills 40 feet in height occur on the east side of the stream. From this point well-marked morainal deposits, ranging up to 75 feet above the bottom of the valley, extend upstream

on the east side for about a mile and a half; in places the deposit consists of irregular hillocks; in places it becomes a distinct ridge near the stream. On the west side of the stream the moraine is not so well marked; in general, however, a somewhat flattened belt on the western slope corresponds in height to the top of the moraine on the eastern side. At 9,200 feet in elevation the steep slopes of the moraine lie on both sides of the stream. The well-marked morainal deposits do not extend above the alluvial flat lying between 9,200 and 9,300 feet.

The higher glacial deposits on the mesa east of Bilk Creek have already been described. On the edge of the mesa to the west, a forest growth obscures the deposit for much of the first two miles south of the San Miguel River; yet within this area at numerous points exposures of characteristic glacial deposits occur, including bowlders in variety. Farther south and continuing as far as the alluvial flat lying between 9,200 and 9,300 feet in elevation, the surface is covered with drift arranged sometimes as ridges, sometimes as irregular hillocks 50 to 75 feet high, inclosing numerous kettles. On the east side opposite the alluvial flat and for two miles downstream, the slope is shorter and steeper, and the topography is less irregular. One distinct ridge occurs, however, extending from about 9,400 to 9,800 feet in elevation, approximately parallel to the medial moraine already described, and lying about a quarter of a mile farther to the southwest. No distinct lateral moraine is found on the east side except for a short distance opposite Magpie Gulch at 9,900 to 10,000 feet elevation.

The maximum thickness of ice in the valley of Bilk Creek was probably about 1,000 feet.

VALLEY OF CANYON CREEK

That part of the valley of Canyon Creek included in the Telluride quadrangle is almost wholly free from glacial débris. *Roches moutonnées* abound, with striae in places. On the west side of the tributary heading west of Stony Mountain, at 12,000 feet in elevation, striae on bed rock bear N. 43° E. Cross has recorded striae near the Trust Ruby Mill along the north branch of Canyon Creek.[1] The topography of the valley as a whole is extremely

[1] *Telluride Folio*, p. 15.

rough and uneven in spite of the general absence of angular points and sharp lines which is due to the smoothing action of the ice. This impression is heightened by the sharp, rugged lines of the precipitous bounding walls. The summit of Stony Mountain is also very rough; it is, therefore, believed to have stood as a nunatak when the ice was at its maximum. Near the western side of the valley, two rock streams occur, one of which is shown in Fig. 8, and a little lower down, at 12,200 feet in elevation, a small lake in a rock basin.

The maximum thickness of ice in that part of the valley of Canyon Creek included in the Telluride quadrangle was probably not less than 1,500 feet.

CIRQUES NORTH OF DALLAS PEAK

The cirques lying northeast, north, and northwest of Dallas Peak were occupied by glaciers which extended northward to an undetermined distance. *Roches moutonnées*, lakes in rock basins, rock streams, talus slopes, and precipitous bounding walls are present here as in the other cirques of the region.

VALLEY OF DEEP CREEK—EAST FORK

In the cirques tributary to the East Fork, lying north of Iron Mountain and Campbell Peak, talus slopes and rock streams are the chief features. The opposite side of the valley has precipitous rock walls in places at the top, with talus slopes below, extending sometimes 1,000 feet down to the stream. Along the main stream, *roches moutonnées* occur at 10,400 feet in elevation on the south side of the stream, and at 11,000 feet elevation between the two cirques lying north of Iron Mountain.

At elevation about 9,700 feet on the west side of the stream, a small accumulation of glacial débris is found. It extends from the stream to the west talus slope, with its surface about 100 feet above the bottom of the valley. It consists of fragmental and rounded bowlders in variety up to 4 feet in diameter. Small depressions exist between this deposit and the talus to the west. No sign of a similar deposit is seen east of the stream at this point; but there is little opportunity for the lodgment of débris on the east side, as the

cliff bank is precipitous. This deposit extends for a distance of about 30 rods along the stream, and is interpreted as a recessional moraine. At its maximum, the ice in this valley extended to the point where the East and the West forks join, at an elevation of about 8,800 feet. The narrow tongue of ice in which this glacier terminated built a lateral moraine 150 to 200 feet in height and three-fourths of a mile long on the south side of this stream from

FIG. 8.—Rock stream northeast of Gilpin Peak at elevation 12,300 feet. Looking east from col at 13,000 feet. Lake partially hidden from view is in a rock basin. Potosi Peak (outside the Telluride quadrangle) is at center in the background.

elevation 9,500 feet to the west side of the West Fork, where bowlders in variety, some of them striated, mark the farthest extent of the ice. On the point between the two forks is an accumulation of glacial débris below the unglaciated point, and on the eastward-facing slope of the East Fork for half a mile above the junction, glacial débris is abundant; above about 9,500 feet in elevation the surface is covered for the most part with talus from

the steep slopes of the ridge west of the stream. Striae on rock in place occur at 9,300 feet elevation on the east side of the stream, with a direction approximately parallel to the valley's course.

The maximum thickness of ice in this valley was probably about 500 feet.

VALLEY OF DEEP CREEK—WEST FORK

The cirques which supplied the ice for the glacier in the West Fork of Deep Creek lie wholly to the north of the Telluride quadrangle. The glacial deposits in this valley are not in general well marked topographically. Glacial débris, including striated bowlders, occurs in abundance on the west side of the stream at an elevation of from 9,300 to 9,500 feet, and for nearly a mile farther down bowlders in variety appear occasionally at the surface. On the east side of the stream a deposit of glacial drift is found, beginning as a shelf at 9,600 feet, changing to the south into a ridge with a slight depression to the east, and extending to an elevation of 9,250 feet. This ridge contains bowlders in variety up to 6 feet in diameter. The lowest point at which drift occurs on the east side of the stream is at an elevation of about 9,000 feet, where it is found at distances ranging up to 60 or 70 feet above the bottom of the valley. In general, the western boundary of the glaciated area is not well marked, as the distinction along the lower part between the glaciated area near the stream and the landslide area to the west and southwest, east of Hawn Mountain, is not clear.

VALLEY OF PROSPECT CREEK

A small glacier of not more than 200 or 300 feet in maximum thickness occupied the upper portion of the valley of Prospect Creek. In the upper part of the valley rounded, projecting points of rock in place occur, and the appearance at the head of the basin is the same as in the other cirque-valleys of the region; that is, precipitous cliffs in a broad arc at the head with talus slopes below. The valley is broad and flat bottomed in cross-section, though having a steep longitudinal profile. In the upper part some ponds occur, together with several small, level, marshy areas, which are evidently the sites of former basins, now silted up.

In the half-mile just above the 10,500-foot line the surface on both sides of the stream is thickly strewn with large angular or

slightly rounded bowlders up to 15 or 18 feet in diameter. Below 10,500 feet in elevation there are few large bowlders; but rounded bowlders in variety occur down to 10,350 feet. Below 10,500 feet the north bank of the stream is steep and shows no sign of morainic topography; south of the stream, however, the surface is less steep and somewhat irregular. Striated bowlders were found at an elevation of 11,200 feet along the trail east from Bald Mountain, at

FIG. 9.—Turkey basin. Looking southeast from elevation 11,700 feet on Bald Mountain, about one mile distant. Note rock stream below patches of snow.

10,900 feet along the trail on the left side of the stream, and at about 10,400 feet on the left side of the stream.

VALLEY OF TURKEY CREEK

Turkey Creek is formed by the junction of a north and a south fork which drain Turkey basin and Alta basin, respectively. Turkey basin is a broadly open cirque, in general flat bottomed, though containing many low ridges and other irregularities of surface (Fig. 9). It contains three lakes, the largest of which has been increased in size by the construction of dams until it has a diameter of nearly a fourth of a mile. In the southeast part a rock stream

nearly a quarter of a mile in length is found at about 11,500 feet in elevation (Figs. 9, 10, and 11). Talus slopes on all sides, and high, steep, rock walls to the southeast form the boundary of the cirque. Alta basin resembles Turkey basin in its broadly open form, its abundant talus, and steep, high bounding walls. It differs chiefly in having a less level bottom, in the absence of distinct rock streams, and in the much smaller size of its lakes.

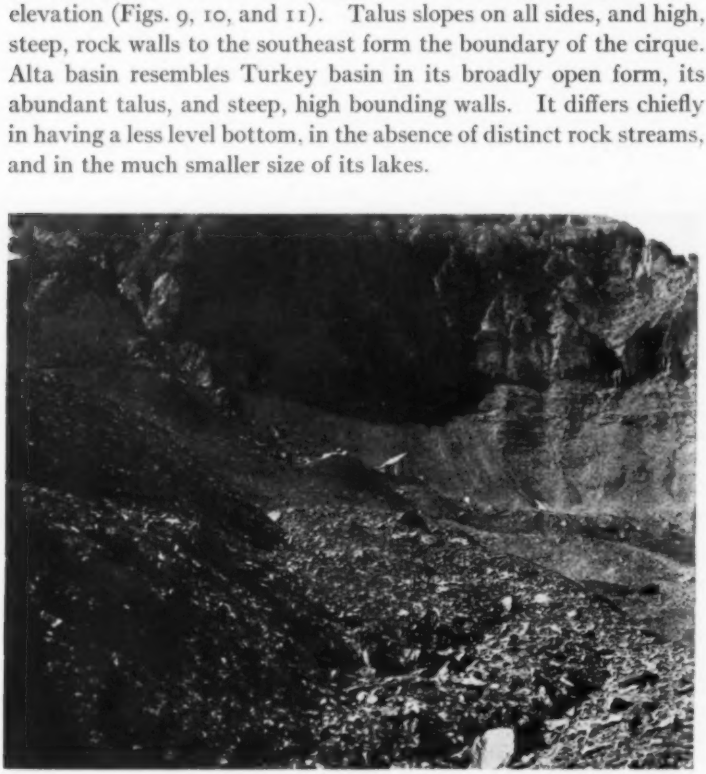

FIG. 10.—West edge of rock stream in Turkey basin. Elevation, 11,300 feet. Looking south. Note also the precipitous wall of cirque above talus slope in background.

Ice from Turkey basin and Alta basin spread over the plateau to the west, covering an area about two miles long by one and one-half miles wide. In this area outside of the cirques, below about 11,000 feet in elevation, the topography is that of ground moraine or terminal moraine; numerous irregular hills inclose kettles 10 to 15 feet deep and up to 100 feet in diameter (Fig. 12, and foreground of Fig. 2). In most directions this hummocky topography

continues to the margin of the glaciated area; on the north side, however, a distinct ridge extends for more than half a mile on the south side of Turkey Creek parallel to its course; and north of the stream, at the margin of the glaciated area, a low ridge lies across the valley of the small tributary heading northwest of Bald Mountain. To the southwest, the uneven moraine topography joins the scarcely less uneven landslide topography.

FIG. 11.—Detail of rock stream in Turkey basin. Elevation 11,300 feet. Looking east across north end of the moraine-like surface.

The maximum thickness of the ice in these two basins probably did not exceed 300 to 400 feet.

VALLEY OF BIG BEAR CREEK

Glaciers from the cirques north and west of Wilson Peak, respectively, united and extended down the valley of Big Bear Creek to about 9,300 feet in elevation. The valley of the cirque heading west of Wilson Peak lies, in part, outside of the Telluride quadrangle; its bottom is broad and less even than is the case in

many other cirques of an equal size. Prominent ridges extend from the head for a mile or more to the northwestward, making a series of small, almost parallel valleys in the bottom of the cirque. In each of these small valleys there are rounded projecting points, some talus, and occasional ponds or small lakes. Viewed from below, the slopes leading to the upper part of the cirque appear abrupt, and, in places, rough and precipitous. Below about 10,400

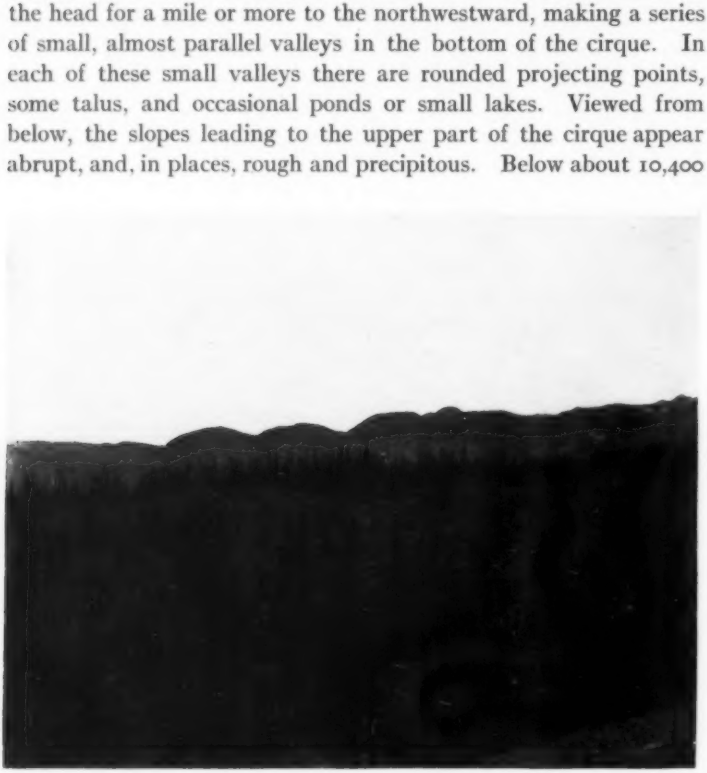

FIG. 12.—Surface of ground moraine, west of Alta basin. Elevation about 10,700 feet. Looking northwest.

feet in elevation the valley of that branch of Big Bear Creek which drains this cirque has prominent moraines. From 10,100 to 10,400 feet in elevation morainal hills are disposed irregularly across the narrow valley, including among them some kettles. On the west, from 10,300 feet in elevation a lateral moraine in places 100 feet high extends northeastward to the limit of glaciation, at about 9,300 feet. A similar ridge lies parallel to the stream on the east side from about 10,200 to 9,600 feet in elevation.

Eastward from these moraines for about two miles the ice spread in a broad sheet, leaving a hummocky, irregular topography. The line of farthest advance of the ice is sinuous, and not marked by any prominent ridges transverse to the valleys; kettles are more abundant, however, near the margin of the moraine than farther back to the south. At different points within the glaciated tract, short ridges of glacial débris with steep slopes occur; but the whole area is covered with a thick growth of spruce and aspen which not only obscures the topography, but often conceals the drift. However, the occasional exposures made by wash of streams, or in the construction of irrigation ditches, furnish abundant evidence of the character of the surface deposits.

An outwash plain of gravel and bowlders extends for about a mile below the edge of the glaciated tract on the east side of the west branch of the stream, having a thickness of from 20 to 30 feet.

The cirque lying north of Wilson Peak resembles closely the one lying next to the east, already described (p. 619). It is broad, shallow, and with unusually high, precipitous walls. As in the cirques just to the east, the underlying rock weathers readily, and *roches moutonnées* and exposed striated rock in place do not occur.

The maximum thickness of the ice was undoubtedly greater in the cirque west of Wilson Peak than in the one to the north, and may have reached 700 or 800 feet.

NAVAJO BASIN AND THE TWO VALLEYS NEXT SOUTH

These three valleys were occupied by glaciers which extended to an undetermined distance beyond the limits of the Telluride quadrangle. That part of Navajo basin included in the Telluride quadrangle is, with the exception of long slopes of talus, almost perfectly cleaned out. *Roches moutonnées* are abundant in the bottom, giving a smooth, regular appearance to the slopes as viewed from the upstream side. As in other cirques, when viewed from the downstream side, a succession of steep slopes appears with some low, rough, precipitous walls.

The cirque next south of Navajo basin is in all essentials like others at equal altitude. The valley is, however, much narrower than Navajo basin, and the talus slopes lying at the foot of the high

bounding walls meet at some points, producing the effect of a valley less well cleaned out. The bottom shows the same alternation of steep and gentle slopes as is found in other cirques.

The second valley south of Navajo basin heads in a shallow, double-headed depression on a steep southern slope. At about 12,500 feet in elevation the generally steep slope is flattened into a shelf or bench perhaps 20 rods in width; back of this shelf the rock wall rises with a steep slope, and on the east and west are short side walls. Below this shelf, talus slopes divided in the middle by a north-south ridge extend down to a second more nearly level area between 11,500 and 11,800 feet in elevation; the topography on this shelf is irregular, and the surface is overgrown with low plants. Below this, steep, rough-faced cliffs appear, at the base of which the more level bottom of the valley begins. The underlying shale is here deeply weathered and eroded in places, showing bare ridges and gullies with but little glacial débris. Farther down the valley, however, glacial drift covers the surface, and a little beyond the edge of the quadrangle typical morainic topography occurs, viz., kettles inclosed by irregular hills containing bowlders in variety, many of which are striated.

At elevation 11,200 feet on the eastern side of the valley glacial drift including bowlders in variety up to 8 feet in diameter forms a ridge extending in a northeast-southwest direction for more than half a mile. The southeast slope of this ridge is gentle, grading off gradually into the unglaciated area; the northwest slope descends to the valley 100 feet or more at an angle of 30° to 35° with occasional exposures due to recent erosion or landslides. This ridge, therefore, constitutes a lateral moraine, the elevation of whose crest above the bottom of the valley is due in large part to the erosion of the underlying formations in which the stream has cut its valley.

The maximum thickness of the ice in Navajo basin and in the valley next south was probably not less than 1,500 feet; in the second valley south of Navajo basin, probably not more than 400 feet.

VALLEY OF KILPACKER CREEK

The cirques at the head of this valley are free from glacial débris. The broader one to the east is cut wholly in a formation of

shale traversed by dikes of igneous rocks. The shale is in places eroded into deep gullies (Fig. 13), leaving bare, gray slopes; in other places landsliding has occurred, resulting in ridges lying

FIG. 13.—East branch of Kilpacker Creek; eroded, bare Mancos shale in center; elevation about 11,300 feet. Lizard Head Peak in background. The eroded floors of cirques with shale as the underlying formation contrast strongly with the *roches moutonnées* of cirques formed in harder rocks.

approximately parallel to the slope, inclosing undrained depressions. The two small cirques near Mt. Wilson have a steep gradient, and

contain some rounded projecting points of rock in place with abundant talus.

From about 11,000 to 10,800 feet in elevation a lateral moraine more than half a mile long lies about a quarter of a mile west of the stream. On the eastern side opposite, there is no distinct ridge of drift, but the somewhat steep slope shows glacial débris at many places. At 10,900 feet in elevation in the bottom of the valley, a small alluvial flat is found, evidently due to the silting-up of a pond. Southwest of this flat the side of the valley is in some places too steep for débris to lie; in other places it is more level, and irregular hillocks inclose kettles. Near the western edge of the glaciated area some landsliding has occurred. In the lower part of the glaciated area abundant glacial débris conceals the bed rock at most points and extends to a height of 300 feet above the stream; bowlders up to 5 or 6 feet in diameter are found, many of them well striated. In the lower half-mile of the glaciated tract the topography of the drift is quite irregular, though some ridges subparallel to the stream occur, as well as a less number of shorter transverse ridges. The lowest point reached by the ice in this valley was at an elevation of about 10,150 feet. Maximum thickness of ice, about 500 feet.

VALLEY HEADING SOUTH OF LIZARD HEAD PEAK

The small cirque lying south of Lizard Head Peak is cut in shale, and its upper part has no glacial drift. The more level part of the cirque ends at about 11,500 feet in elevation; below this for about a quarter of a mile the gradient is steeper and the stream flows for a part of the way in a canyon having for its right wall a precipice of igneous rock, in places 75 to 100 feet high, and for its left wall a steep talus slope.

The lower limit of glaciation in this valley was a little below 10,200 feet in elevation. At this point is a broad transverse ridge of drift 10 feet high, extending from the stream eastward for 100 yards. Another similar transverse ridge, perhaps 15 feet high, occurs 20 rods farther upstream. The slopes of the valley are covered with drift up to 200 or 300 feet above the stream; the deposit on the west side of the stream is apparently more abundant

than on the east, and is partially arranged in ridges approximately parallel to the stream's course.

The maximum thickness of ice in this valley was probably not more than 300 feet.

VALLEY OF WILSON CREEK

The glacier which occupied the valley of Wilson Creek was in the shape of a crescentic sheet concave toward San Bernardo Mountain. A short morainal ridge southeast of San Bernardo Mountain at 10,700 feet to 10,800 feet in elevation marks the lower limit of the ice to the east. Northward, down the valley of Wilson Creek, the ice extended to nearly 10,200 feet in elevation, crossing the stream at this point; above this point is a lacustrine flat which extends for nearly a mile along the stream.

Above timber line to the west are the accumulations of talus and precipitous rock walls usually found in glacial cirques in this region. On the south the slope north of Black Face Mountain is mostly free from talus; some points are smoothed as if by the action of ice, but over most of the surface a thin covering of soil scarcely concealing the rock in place supports a growth of low plants. No precipitous wall is found on the south; the valley slope gradually flattens at the top to form the rounded crest of the ridge, which on its southern side is steep and furrowed with V-shaped gullies. Southeast of San Bernardo Mountain, above the short moraine already mentioned, the glacial deposits show an uneven surface at a few points, inclosing two or three ponds. On the west side of the valley north of east from Lizard Head, a morainic ridge at 10,800 feet in elevation extends for a quarter of a mile in a north-south direction. Over most of the area, however, the surface is irregular.

The lower slopes of the valley on both sides of the stream above the flat are heavily wooded at most points, obscuring to some extent both the topography and the composition of the surface deposits. At numerous points on the eastward-facing and northward-facing slopes, however, glacial drift is exposed, including bowlders in variety, some of which are well striated. In this respect these slopes are in sharp contrast to the southward-facing and westward-facing slopes of San Bernardo Mountain, where rock fragments are

rare, shale exposures abundant, and topography due to landsliding often clearly evident.

The maximum thickness of ice in this valley was probably not more than 200 to 300 feet.

VALLEY OF THE EAST DOLORES RIVER

Glacial ice descended the valley of East Dolores River to an elevation of 9,550 feet. Ice was continuous from this point up the north branch over Lizard Head Pass, up the main valley to the cirques south of Sheep Mountain, and to the top of Flat Top Mountain. Southwestward from Lizard Head Pass, two lacustrine flats mark the position of silted-up lakes. Over most of the remaining surface up to 100 or 200 feet above the stream, glacial drift is abundant. At no point in the Telluride quadrangle was drift found containing a larger proportion of striated bowlders than along the north side of this valley below Lizard Head Pass. The topography on the south side of the stream is more uneven than on the north, but a forest growth has made the determination of the composition of the surface deposits more difficult. The 10,200-foot hill lying in the valley a mile and a half below the pass has a core of igneous rock overlaid by drift. At the point where the stream changes its course to nearly due south, rock in place is exposed on the west side of the stream and drift is not abundant. On the east side, however, morainal hills continue to the junction of the two branches of the stream.

The upper boundary of the glaciated area on Flat Top Mountain is a 25° to 30° slope of bare shale 40 to 50 feet high, extending in an east-west direction for about half a mile. This steep, northward-facing slope lies a little south of the southern boundary of the Telluride quadrangle. From 11,800 to 10,500 feet in elevation *roches moutonnées* are abundant, and in many places show striae bearing northeast of north, in general parallel to the course of the stream. To the northeast, the northwest, and the west, lobes of ice extended to the edge of the steep, precipitous slopes of igneous rock. Along the valley to the northwest, down to about 11,000 feet in elevation, *roches moutonnées* and striae are abundant. The valley leading northward to the Dolores River is a broad ravine in

its lower part, with morainal deposits below about 10,500 feet in elevation. On the east side of the valley a distinct lateral moraine extends from about 10,400 to 9,800 feet elevation, the upper end being farther from the stream than the lower. On the west side a morainic ridge extends from about 10,000 feet in elevation down into the valley of the Dolores River. The glacier on Flat Top Mountain probably did not exceed 200 feet in thickness at the maximum. Its action was not vigorous, and probably only a small portion of the whole mass of ice reached the valley of the Dolores River.

The source of the largest amount of ice entering the valley of the East Dolores River was in the cirques south of Sheep Mountain. Above 12,000 feet in elevation the cirques show the usual variations in gradient, some cliffs from 60° in slope to perpendicular, some slopes more gentle, 10° to 20° with irregular topography due in part to weathered heaps of talus, in part to irregularities of the rock floor. Back of the last more level portion are the slopes of bare talus and the precipitous bounding walls. Below 12,000 feet in elevation the rock in place is largely obscured by weathered rock waste and glacial drift which in places supports a considerable forest growth.

At the point where the stream draining the two cirques enters the East Dolores River, drift hills are abundant on the east side of the river. The edge of the ice here pushed up the valley of the East Dolores to the south for a half a mile, leaving a moraine at 10,250 feet in elevation with its top 30 to 40 feet above the stream. For nearly a mile and a half on the north side of the stream draining the two cirques drift hills cover the slope up to about 500 feet above the stream. In some places the topography is irregular, but more often there are more or less distinct ridges, either approximately parallel to the course of the stream, or tending to become oblique by an approach of the ridge to the stream in the downstream direction. South of the stream the drift hills continue up to about 10,600 feet in elevation. In the drift on both sides bowlders occur in variety, many of them striated. Above the well-marked drift hills, frequent accumulations of glacial débris, in some cases inclosing undrained depressions, continue for a half a mile or more.

In the valley of the East Dolores northeast of Flat Top Mountain drift is abundant on both sides for half a mile or more above the junction of the two branches. Farther upstream, on the west side, the surface is almost wholly covered with talus from the precipitous outcropping igneous rock. On the east side drift is found near the stream below the outcropping cliff face, and in places on the more level area above the outcrop. The westward-facing slope for more than a quarter of a mile above the boundary as determined for the more recent stage of glaciation contains evidence of the presence of ice of an earlier epoch. The line of division between these two areas is, however, drawn somewhat arbitrarily, its position being determined in part by a comparison of the elevations of the limit of recent glaciation at points respectively farther up and farther down the valley. As finally determined the line represents approximately the line of division between abundant drift on the surface (recent epoch) and occasional, disconnected patches of drift (earlier epoch).

The drift hills near the junction of the two branches are, in general, irregular in arrangement, and less prominent below the junction than above. On the north side, however, at 9,900 feet elevation, a distinct lateral moraine occurs extending for 40 rods in a northeast-southwest direction. Lower down on the slope at 9,700 to 9,800 feet elevation is another fragment of a morainic ridge parallel to the one first named. These ridges are distinguished as morainal from somewhat similar ridges and terraces farther up the slope which are due to landsliding, chiefly by their composition, but also by their greater length and regularity. The lower limit of extent of the ice is marked only by small accumulations of drift on the somewhat steep slope. Below this point valley train deposits occur west of the mouth of Kilpacker Creek and again at various points on the south side of the stream up to 30 feet above the bottom of the valley.

The maximum thickness of ice in the valley of the East Dolores was probably about 500 feet.

VALLEY WEST OF GRIZZLY PEAK

That part of the head of the cirque lying northwest of Grizzly Peak on the north side of the stream presents the same features as

the cirques lying south of Sheep Mountain. The slopes on the south side of the stream, however, and the ridge bounding the valley on the south are distinctly different. These slopes are covered with bare talus and show an uneven, hilly topography due to the weathering of numerous irregularly disposed bosses of outcropping rock. The rock in place is completely mantled with angular fragments, and on the west and northwest sides of Grizzly Peak the long, steep talus slopes extend practically to the summit of the mountain, giving to this part of the cirque an appearance which contrasts sharply with the usual precipitous walls which bound most of the other cirques.

Glacial ice of the more recent epoch extended down to about 10,700 feet in elevation. At this point the glacial deposits are best preserved on the north side of the stream, where drift hills 150 feet high show a slope of about 30° both to westward and to southward. For about half a mile eastward on the upper part of the slope on the north side of the stream, drift occurs containing bowlders up to 8 feet in diameter, some of which show striations. Drift with striated bowlders also occurs on the south side of the stream, but a small tributary not shown on the topographic sheet either has prevented the deposition of as large an amount, or has carried away much of what was deposited. The lower part of the glaciated area, up to about 11,500 feet in elevation, is mostly forest-covered. The topography is irregular, with some undrained depressions.

The maximum thickness of ice in this valley was probably about 300 feet.

CIRQUE-VALLEYS TRIBUTARY TO THE ANIMAS RIVER

All the cirques and valleys lying in San Juan County in the southeast part of the Telluride quadrangle are drained by tributaries of the Animas River. With the exception of deposits on the north side of the stream eastward from Ophir Pass and in the lower part of the valley next south, where drift hills with striated bowlders occur up to 400 feet above the stream, these valleys and cirques are all practically free from glacial débris (Fig. 14). In general, abundant talus covers the slopes at the base of steep cliffs, while on the more level portions more or less well-developed *roches moutonnées* are found. In many places the rock in place weathers

too readily to allow striae to be preserved, yet at the following points excellent examples are to be seen:

1. Southeast of Rolling Mountain on the northward-facing slope, numerous striae parallel to tributary streams; average bearing about N. 7° W.

FIG. 14.—Cirque three-fourths of a mile north of Grizzly Peak, tributary to valley of Cascade Creek. Elevation 12,500 to 13,000 feet. Looking south of west from southward-facing slope at head of valley of Cascade Creek.

2. Southward from this slope along the trail over the pass into the valley tributary to Cascade Creek, at 12,500 feet elevation, bearing N. 77° W.

3. South of Twin Sisters Mountain, one-half a mile from the south boundary of the quadrangle, at 12,000 feet elevation, bearing S. 77° E.

4. East side of pass along the trail leading from the Trout Lake branch of Lake Fork to the South Fork of Mineral Creek, at elevation 12,000 feet, bearing S. about 75° E.

5. In the upper part of the valley of Mill Creek, at 12,500 feet elevation, three-fourths of a mile from the eastern boundary of the quadrangle, bearing nearly due east.

Lakes and ponds in rock basins, most of which are of sufficient size to be mapped, occur in the following valleys:

1. Valley of Lime Creek southwest of Twin Sisters Mountain, at an elevation of from 12,000 to 12,500 feet.

2. South Fork of Mineral Creek south of Beattie Peak, at 11,500 to 12,000 feet elevation.

3. Ice Lake basin, at 11,500 to 12,800 feet elevation.

4. Clear Lake, one mile east of U.S. Grant Peak, at 12,000 feet elevation.

5. East of Ophir Pass, at 12,000 feet elevation.

6. Mill Creek basin and cirque next south, at 12,000 to 12,500 feet elevation.

Rock streams are found in the south part of Paradise basin, and to the north and west of Twin Sisters Mountain. In the valley of Cascade Creek at 11,200 feet elevation a small alluvial flat occurs such as is due to the silting-up of a pond or lake.

The maximum thickness of ice in these valleys was in the South Fork of Mineral Creek where it must have reached more than 1,500 feet; the maximum in the valley of Cascade Creek was probably not much less.

ON THE STRATIGRAPHIC POSITION AND AGE OF THE JUDITH RIVER FORMATION

A. C. PEALE

PART II

THE STRATIGRAPHIC POSITION

Hayden, who was the first to note and study geologically the Judith River beds, and to whom the name is due, gives the first published section of them as he found them in the type region near the mouth of the Judith River, following it with a section of the marine strata (Fox Hills) immediately underlying them. Combining these two sections into one we have the following:[1]

HAYDEN'S SECTION OF JUDITH RIVER BEDS[2]

"Section of fresh water and estuary deposits at the mouth of the Judith River"

JUDITH RIVER FORMATION

TOP

	FEET
Yellow arenaceous marl passing downward into gray grit, with seams of impure lignite with *Ostrea subtrigonalis, Cyrena occidentalis, Melania convexa,* and *Paludina Conradi*	80
Impure lignite, containing much sand with Ostrea	10
Alternations of sand and clay with particles of lignite; also reddish argillaceous concretions with a few saurian teeth and fresh-water shells	80
Alternate strata of sand and clay, with impure lignite and silicified wood, in a good state of preservation	20

[1] *Trans. Amer. Phil. Soc.*, II, N.S., Philadelphia, 1860, pp. 129, 130.

[2] Hayden, according to his habit, constructed his general section from "a large number of local sections" "taken at different points." This is the only section of these beds ever published by him. The type locality is shown on the map (Pl. 8) opposite p. 154, in the area marked "B. L. (Badlands of the Judith)" overlooking the mouth of the Judith River, and is the only locality on the map so marked along the entire course of the Judith River. Hence it must be considered the *type locality*. Professor F. B. Meek says that the Judith River Group was "first examined by him [Dr. F. V. Hayden] at the typical locality near the mouth of the Judith River on the upper Missouri River in Montana."—*U.S. Geol. Surv. Terr.*, IX, p. xlvii.

	FEET
Variable bed, consisting of alternations of sand and clay, with large concretions, with species of Melania, Paludina, Helix, Planorbis, Cyclas, Iguanodon, and Megalosaurus	100
Alternations of impure lignite and yellowish-brown clay with Unio, Paludina, Melania, Cyclas, and Lepidotus	25
Ferruginous sand and clay, having in the upper part a seam 3 or 4 inches in thickness composed mostly of shells of *Unio*. Lower part ferruginous and coarse gray grit with a seam near the base entirely composed of remains of *Unio Danai, U. Deweyanus, and U. subspatulatus*	100

FOX HILL'S FORMATION

Yellowish and reddish, rather coarse-grained sandstone, becoming deep red on exposure with *Inoceramus ventricosus*, *Mactra alta*, and *Cardium speciosum*	20–25
Mixed pure and impure lignite—whole bed containing many crystals of selenite and a yellowish substance like sulphur. The masses of lignite when broken reveal in considerable quantities small reddish crystalline fragments of a substance having the taste and appearance of rosin	6–8
Variable strata of drab clay, and gray sand and sandstone. Near the middle there are gray or ash-colored clays with very hard bluish-gray granular siliceous concertions with *Ostrea glabra, Helangia americana, Panopea occidentalis*, and *Mactra formosa*	80–100

The table given on p. 642 gives the list of species collected by Hayden in the beds [Fox Hills] underlying the Judith River beds as identified by Professor F. B. Meek,[1] together with their outside distribution in other parts of Montana, the Dakotas, and Colorado. In the last column is shown the recurrence of these species in Stanton's Claggett formation, which apparently occupies the same position in relation to the Judith River beds, including without doubt the beds shown in Hayden's section, which are identical with the sandstones found by the writer at the top of the dark Pierre shales and below the lighter-colored clays, sands, and shales of Judith River age. In these lower sandstones invertebrate fossils of Fox Hills age were found.

[1] *Report U. S. Geol. Surv. Terr.*, IX (1876), 1–506.

Fox Hills Species from Mouth of Judith River (Immediately underlying Judith River Beds)	Distribution in Fox Hills of Other Localities				
	Wyoming near Parkman and in Converse County	North and South *Dakota* Mainly on Indian Reservations	*Colorado* Denver Basin and Eastern Colorado	*Colorado* Mainly on White River in North-Western Colorado	From Chagett Formation as described by Stanton (immediately underlying Judith River Beds)
Inoceramus pertenuis	..	..	..	×	..
Inoceramus crispii cubcompressa	..	..	..	..	..
Mytilus subarcuatus	..	..	×	..	..
Tancredia americana	×	×	×	..	×
Cardium (Cricocardium) speciosum	×	..	×	×	×
Callista (Dosiniopsis) Owenana	..	..	×	..	..
Tellina (Peronaea) equilateralis	×	..	×	..	..
Mactra (Cymbophora) formosa	..	..	×	..	×
Mactra (Cymbophora ?) alta	..	..	×	×	..
Pholadomya subventricosa	..	..	..	..	×
Thracia subtortuosa	×	..	..	..	..
Thracia gracilis	..	..	×	..	×
Thracia (?) prouti	..	..	..	..	..
Liopistha (Cymella) undata	×	..	×	..	×
Glycimeris occidentalis	..	..	..	..	..
Lunatia subcrassa	×	×	×	..	×
Vanikoropsis Tuomeyana	..	..	..	..	×
Baculites asper	..	..	..	..	..

Stanton's Section on East Side of Cow Creek

		FEET
Judith River Beds	Middle portion covered in bed of creek. One hundred and fifty feet of lower Judith River beds are continuously exposed in the upper section, and one-half mile east, where the Judith River beds are horizontal, a thickness of 490 feet was measured, but the base is not exposed at this point. A shale bed about 30 feet above the base of the formation yielded many leaves of *Trapa (?) microphylla*, together with abundant fresh-water Mollusca, including *Sphaerium recticardinale. Physa copei (?), and Goniobasis subtortuosa.* Another horizon about 300 feet from the top, in the exposure one-half mile east of the section, yielded *Sphaerium planum, Anodonta propatoris, Unio danae (?), Unio primaevus, Valvata montanaensis, Hyalina? evansi, Hyalina(?) occidentalis, Planorbis amplexus, Physa copei Goniobasis subtortuosa,* and *Goniobasis gracilenta*	490

		FEET
Claggett Formation	*c*) Light-colored shales or sandy clays with band of brown sandstone containing *Tancredia americana* in middle. Top of marine	50
	b) Yellowish-brown sandstones, generally soft, but with harder layer and lenses, with *Tancredia americana, Cardium speciosum, Tellina equilateralis, Liopistha* (*Cymella*) *undata, Lunatia, subcrassa, Baculites* sp., and fragment of vertebrate jaw	20
	a) Dark shales with concretions bearing *Baculites ovatus, B. compressus, Nucula cancellata, Leda* (*Yoldia*) *evansi*, and *Gervillia borealis*. These shales weather much as the Bearpaw, but with a reddish tinge. The concretions are different with fewer fossils and not so great a variety. These beds become lighter toward the top, the upper 50 feet containing two seams of thin brown sandstone, each 2 to 3 feet thick	300–400
	Total thickness of Claggett	370–470
Eagle Formation No fossils	*e*) Cross-bedded and finely laminated sands with thin seams of lignites, in places becoming more massive	125
	d) Very light-colored, fine, heavy-bedded sandstone	40
	c) Heavy-bedded buff sandstones, soft at base, but harder above, and with indurated lenses and numerous large concretions, weathering brown at the top. The thickness of *b* and *c* is very variable	50
	b) Heavy-bedded buff sandstones with lenses of lignite and shales sometimes exhibiting cross-bedding	30
	a) Regularly-bedded buff sandstones with several thin seams of dark shales	20
	Total thickness of Eagle formation	265
Dark Benton Shales	Baculites and other invertebrates in concretions, and containing several layers of sandstones in upper 100 feet. The following fossils were found in these shales near the base: *Inoceramus* sp., fragments of a thick-shelled form; *Prionotropis*(*?*) sp., fragment; *Scaphites ventricosus; Baculites* sp., a slender, strongly nodose form. Several genera of invertebrates not specifically determinable were collected in the upper portion	300

The section by Stanton and Hatcher was made north of the Missouri in the disturbed region, but is apparently the normal section corresponding closely to those taken by us on the Judith River, at several places south of its mouth. As published, however, 500 to 700 feet of supposed Bearpaw shales, including light-colored sands and shales at the base, are added by Stanton above the Judith River beds. These have not been included by us as they were not in his section as shown one mile below their camp but were *added from exposures noted west of their camp.*[1] In some of his localities, as on the Birch Creek, he says:[2] "The overlying Bearpaw shales are not represented in this immediate region, having been entirely removed by erosion." In other places what *appear* to be Pierre shales seem to overlie the Judith and there is little doubt that in some cases they do actually occur at higher levels, as we saw at Mauland, but until a careful areal survey is made of the whole region it will be impossible to say whether the beds are below and of Belly River age, or whether the case is as at Mauland, where the cause of the apparent superposition is one of the numerous faults traversing the region. In Dr. Stanton's section given above there is no doubt but that 70 feet or more of the beds referred to the Claggett are of Fox Hills age, while the 300–400 feet of dark shale immediately below should be referred to the Pierre. These shales, Dr. Stanton says, "weather much as the Bearpaw" and contain concretions containing Pierre fossils. Stanton and Hatcher[3] say in their description of the Claggett:

> In the neighborhood of Judith (old Fort Claggett), where they are well exposed, they have a total thickness of about 400 feet and consist largely of dark clay shales with variable intercalated bands and beds of sandstone, especially in the upper half. The dark shales of the lower part of the formation contain many calcareous concretions, which yield *Gervillia borealis*, *Baculites ovatus*, *Baculites compressus*, and a few other forms, elsewhere regarded as characteristic of the Fort Pierre. The yellowish sandstone beds higher in the formation, especially one about 200 feet from the top and another near the summit, are often locally very fossiliferous, and bear an invertebrate fauna, of which the most conspicuous species are the following:

[1] *Bull. U.S. Geol. Surv., No. 257*, p. 44.

[2] *Ibid.*, p. 40.

[3] *Ibid.*, p. 13.

Species from Upper Part of Claggett Formation

Tancredia americana	Mactra formosa
Cardium speciosum	Mactra alta
Sphaeriola? endotrachys	Lunatia subcrassa
Tellina equilateralis	Vanikoropsis tuomeyana
Thracia gracilis	Baculites sp.
Liopistha (Cymella) undata	

This has long been considered a typical "Fox Hills" fauna, and a number of its species do recur at the top of the marine Cretaceous immediately below the Laramie in Colorado and elsewhere.

The table already given of the Fox Hills fauna lying below the Judith River contains a list of 18 species of which four, so far as the writer can learn, have not yet been found elsewhere in the Fox Hills. Out of the remaining 14, 10 have been collected in the Fox Hills beds of eastern Colorado, while 8 have been found in the Claggett of Stanton, which seems not only to contain a "typical Fox Hills" fauna but also to hold the same stratigraphic position. The Fox Hills beds of Canada occupy the same position also, but they are, according to Dawson, McConnell, and Tyrrell, so inconstant that they have been considered as a whole with the Pierre and the two faunas have not been differentiated.[1] This inconstancy of the Fox Hills beds, especially so far as thickness goes, has also been everywhere noted south of the international boundary line, ranging from nothing (that is, in some places the overlying beds—Lance and Judith River—rest on the Pierre shales) to 800 or 1,000 feet. This last is the thickness in the Denver basin of Colorado as given by Eldridge.[2] In one place only, in Colorado, does it fall much below 1,000 feet. This is at Golden, where the thickness is only 500 feet, which Eldridge attributes to the nondeposition of the lower part. This thickness of 500 feet is about the same as noted by us in 1910 in south-central Wyoming. As to the shells in this Colorado section Eldridge says:[3]

While the invertebrate fossil remains occur throughout the entire thickness of the Fox Hills, there is an especially conspicuous array of characteristic forms at the very summit of the formation, in the uppermost layer of the capping sandstone, none of which is ever found above, and but few of which are met with in numbers below.

[1] *Contribution to Canadian Paleontology*, I, 29.

[2] *Monographs U.S. Geol. Surv.*, XXVII (1896), 71.

[3] *Ibid.*, p. 72.

In the table already given, of the species listed in the column under "Denver Basin and Eastern Colorado," more than half the number came from the very summit of the formation where there is no admixture of Pierre forms. Curiously enough, too, the list for the beds below the Judith River in Dr. Stanton's section on east side of Cow Creek (see pp. 642–43) suggests no mingling of Pierre and Fox Hills forms, such as is so clearly shown in the collections made on the Yellowstone River about 150 miles above its mouth.[1] Whether this indicates a condition in the Judith basin similar to that noted by Eldridge at Golden will have to be left to the result of future careful study of the Fox Hills outcrops. It is more than likely, however, that, as stated by Professor Meek:[2] "These beds underlying the brackish-water lignite [Judith River] beds form an upper member of the Fox Hills group."

The mingling of the Fox Hills and Pierre faunas has been noted, but to a more limited extent, also in the Dakotas where, however, as we have indicated, the entire thickness of the Fox Hills is not seen. Indeed, it is questionable whether a full development of the formation occurs anywhere in this area. At the top of the Fox Hills sandstone, which has a marine fauna, Dr. Stanton found a thin and widely distributed bed with a brackish-water fauna which he regards as belonging to the Fox Hills rather than to the overlying Lance formation, an interpretation that is not in accord with the views of the field geologists studying the area, who placed it immediately above the unconformity which marks the contact of the Lance on the Fox Hills.[3] Similar brackish-water faunas are found, according to Dr. Stanton, wherever the Judith River formation is found "intercalated in the upper and lower portions of the formation."[4] This occurrence, just referred to as at the base of the Lance formation, is on the line of the unconformity which,

[1] *Report U.S. Geol Surv. Terr.*, IX (1876), p. xxxiv.

[2] *Ibid.*, p. xxxvi.

[3] *Amer. Jour. Sci.*, XXX (September, 1910), 178.

[4] *Bull. U.S. Geol. Surv., No. 257*, p. 120.

The entire quotation is: "The brackish fauna has a wide geographic distribution occurring in practically every area in which the Judith River formation is found, but it is confined to thin beds intercalated in the upper and lower portions of the formation."

according to Knowlton,[1] is so widely recognizable. Referring to this mingling of forms at the base of the Lance, Knowlton says:[2]

> Because Fox Hills fossils occur in the lignitic shales at the base of the "somber beds" and mingled with the brackish-water types of the Lance formation is not necessarily proof positive that the various faunas lived at the same time; for if the deposition of the Fox Hills was followed by a definite erosion interval, what is more probable than that in the deposition of succeeding strata fossil shells would be eroded from the marine beds and carried into channels, there to mingle with the then living brackish-water fauna of the Lance formation?

A reference, at this point, to the Canadian section will be of interest as proving the existence of two series of fresh-water beds, the lower one of which was named the Belly River series by Dr. G. M. Dawson in 1882.[3] He had previously described in his report on the geology and resources[4] in the vicinity of the 49th parallel an upper series of fresh-water badland beds lying south of Wood Mountain, which he referred to the Lignite Tertiary and an underlying series thought to correspond to the Fox Hills group.[5] By the Lignite Tertiary, Dawson meant the Fort Union group of Hayden; and he also correlated the beds with the Judith River beds. The same beds are later described as the Laramie (Edmonton and Paskapoo) by the other Canadian geologists.

Later in his last report,[6] without having revisited the region south of Wood Mountain, Dawson relegated these beds to the Belly River series, and says: "The beds thus separated as the Belly River series were, in 1875, by me, correlated with the Judith River series of the Missouri." Dawson had evidently been misled by the lithological resemblance between the two series. On p. 117*c* of the report just cited he says: "The Belly River series has

[1] *Proc. Wash. Acad. Sci.*, XI (1909), 170–238; *Jour. Geol.*, XIX (1911), 360–776.

[2] *Ibid.*, p. 365.

[3] *Geol. Surv. Canada, Report for 1880–82*, Montreal, 1883, pp. 1B–8B. On p. 1 reference is made to a note published by Dawson in May, 1882, in which he says "the following report is essentially a reprint."

[4] *British North American Boundary Commission Report on the Geology and Resources in the Region in the Vicinity of the 49th Parallel*, Montreal, 1875, pp. 103–58.

[5] *Ibid.*, p. 156.

[6] *Geol. Surv. Canada, Report of Progress, 1882–84*, Montreal, 1885, "Report of the Region in the Vicinity of Bow and Belly Rivers, 1884," pp. 118*c* f.

not yet been definitely identified in any part of the disturbed belt bordering the mountains, where, from the complicated character of the sections and absence of fossils, it is difficult to discriminate between it and the lithologically similar beds of the Laramie." By Laramie, Dawson meant the beds which overlie the Fox Hills Cretaceous, including his Porcupine Hills and St. Mary's series, or, as the Canadians name them later, "Paskapoo" and "Edmonton." As Dawson says,[1] it is not intended by its [Laramie] use to differentiate the beds so named from those of the Judith River and Fort Union series, with which they may be found to blend as the intervening district is more completely explored. That Dawson was not himself satisfied is shown by the fact that in the same report, pp. 125, 126, he suggests an alternative explanation which involves the existence of an unconformity at the base of the Judith River formation. The evident confusion in trying to differentiate between these "Laramie" beds (Dawson) and the Belly River beds was not cleared up until more complete stratigraphic examinations were made by R. G. McConnell[2] and J. B. Tyrrell.[3]

McConnell, when considering the stratigraphical position of the Belly River beds, writes as follows:[4]

> The doubt which existed at one time in regard to the stratigraphical position of the Belly River series, on account of the Laramie *facies* of its invertebrate fauna, has been removed by a more complete examination of its eastern margin. Its line of contact with the Pierre has now been traced, through a distance of over 150 miles, by numerous exposures, all of which afforded the clearest possible proof of its subordinate position. The junction is marked in many places by low plateaus (see p. 41), which offer exceptional facilities for noting the relations of the two formations, as they owe their origin directly to the superposition of a protecting covering of the less easily eroded dark shales on the light-colored beds below. The western slopes of these plateaus are usually bare, and the line of contact between the two dissimilarly colored series distinctly drawn. A reference to the general section which accompanies the map will also show that at the west end of the Cypress Hills, the Laramie and Belly River series, separated by the Pierre shales, occur in what is practically the same section, and as the beds have been so little disturbed that their maximum dip seldom exceeds ten feet to the mile, and consequently no question of over-

[1] *Geol. Surv. Canada, Report for 1880–82*, Montreal, 1883, p. 2B.

[2] *Geol. Surv. Canada*, I, "Report for 1885," Montreal, pp. 1–85*c*.

[3] *Ibid.*, II, "Report for 1886," Montreal, pp. 1–176*e*.

[4] *Ibid.*, p. 64*c*.

turn or dislocation is involved, no better stratigraphical evidence can possibly be offered.[1]

Tyrrell's work in 1886[2] was in the northern part of Alberta and the western edge of both Assiniboia and Saskatchewan on drainage tributary to Red Deer River, Ghost River, Bow River, and both the North and South Saskatchewan. His section in this area from the Belly River series to the Laramie, including both, is as follows:

	FEET
Laramie	
Paskapoo Series: Gray and brownish weathering, lamellar or massive sandstones, and olive sandy shales. This is an exclusively fresh-water deposit.....	5,700
Edmonton Series: Soft whitish sandstones and white or gray, often arenaceous, clays, with bands and nodules of clay, ironstone, and numerous seams of lignite. These are of brackish-water origin and correspond to the lowest portion of the St. Mary River series of Dr. Dawson's Report (*Geol. Survey Report for 1882–84*, p. 114*c*)	700
Fox Hills and Pierre	
Brownish weathering sandstones and dark gray clay shales	600
Belly River Series	
Soft, whitish sandstones and arenaceous clays, changing toward the east to light-brownish and yellowish sandstones and sandy shales, bottom not seen.....	

From what we have detailed in the preceding pages, it seems impossible to avoid the conclusion that the stratigraphic position of the Judith River beds is *above* the Fox Hills sandstone which in turn rests on the Pierre shales. The Judith River thus holds exactly the same interval in the geological column that is occupied by the Lance formation and not that of the Belly River series of Canada, nor that noted for their equivalent beds in the United States. The lithological resemblance between the beds of the Belly River series and the Judith River formation does not count for much and is no greater than that between the Lance formation and the Judith River beds. Dr. Stanton,[3] referring to the Belly River series, says:

[1] Mr. McConnell in reply to an inquiry makes the following statement to the writer: "I have had no reason to change my mind in regard to the relative positions of the Belly River and Pierre formations as given in the report you refer to. I have not done any work in recent years on the plains, but the work done by others of the Survey has all been confirmatory."

[2] *Geol. Surv. Canada*, II, "Report for 1886," Montreal, p. 5*c*.

[3] *Bull. U.S. Geol. Surv., No. 257*, p. 26.

R. G. McConnell and J. B. Tyrrell confirmed Dr. Dawson's conclusions concerning the stratigraphic position of the Belly River series so far as the overlying beds were concerned but still left the exact age of the underlying formation undetermined.

They could hardly have done otherwise as their sections in both cases did not go to the base of the Belly River series, but in the Saskatchewan and Peace River districts Benton shales[1] were found by Dr. G. M. Dawson below the Niobrara, to which latter formation Dawson and the other Canadian geologists referred the beds afterward relegated to the Belly River series. It was here that the Dunvegan sandstones, which lie above the Benton, were named; and these Dunvegan sandstones Dawson was always inclined to correlate with the Belly River series. The flora of this Dunvegan series, which Sir William Dawson says is very nearly akin to that of the Dakota group, "accords with the stratigraphical position assigned the beds, namely below the horizon of the Fort Pierre Cretaceous."[2] The following section is given by Osborne on p. 9, in Vol. III, Part II, of *Contributions to Canadian Paleontology:*

PROVISIONAL CORRELATION

Fresh water	Paskapoo* (no dinosaurs)	Ft. Union†	
Brackish and fresh water	Edmonton	Laramie and Judith River	Triceratops, Torosaurus, Dryptosaurus, Ornithomimus
Marine	Pierre-Fox Hills Group	Fox Hills Fort Pierre	
Fresh and brackish water	Belly River	Montana exposures in part	Stereocephalus, Monoclonius, Ceratops, Trachodon, Deinodon, Ornithomimus, Compsemys, Ptilodus
Sandy clays and sandstones	910 feet	(Niobrara)	
	Ft. Benton	Ft. Benton Dakota	

* Regarded by Tyrrell as the beginning of the Tertiary.
† Mammals of Puerco type discovered by Douglas in 1901.

[1] *Geol. Surv. Canada, 1879–80*, Montreal, 1881, p. 133B.

[2] *Ibid.*, pp. 119–23B.

There is, therefore, little, or no doubt as to the beds underlying the Belly River series in Canada. On our side of the line, we were fortunate enough to see complete sections from the Jurassic up into the Fort Union on Fish Creek, where the Belly River beds lie above the Eagle sandstones with an intervening alternation of sandstones and sandy shales that could not in any way be confounded with the characteristic soft dark shales of the Pierre that rest on the horizontal fresh-water badland bed of Belly River age.

COMPARATIVE SECTIONS SHOWING RELATIVE POSITION OF BELLY RIVER AND JUDITH RIVER FORMATIONS

		Colorado and Wyoming		Montana			Canada
		Eastern Colorado	Wyoming	Judith River Section	Fish Creek Section	Willow Creek Section	
Eocene Tertiary	Ft. Union		Upper Fort Union		Fort Union	Fort Union	Paskapoo
			Lower Fort Union (Lance)	Judith River	Lance	Lance	Edmonton
	Shoshone	Denver			Livingston	Absent	
		Arapahoe					
Upper Cret.	Lara.	Laramie	Laramie	Absent	Absent	Absent	Absent
	Mont.	Fox Hills	Fox Hills	Fox Hills	Fox Hills	Absent	Fox Hills
		Pierre	Pierre	Pierre	Pierre	Pierre	Pierre
Middle Cret.	Colo.	Niobrara	?	Belly River Eagle	Belly River Eagle	Belly River Eagle	Belly River Dunvegan
		Benton	Benton	Benton	Benton	Benton	Benton
	Dak.	Dakota	Dakota?				Dakota?
Lower Cret.		Comanche		Kootenai	Kootenai?		Kootenai
		Morrison		Morrison	Morrison		

In the accompanying correlation table of local sections the line of unconformity between the Cretaceous and Tertiary is shown by the double line, which, in Colorado, indicates the break between the Arapahoe and the Laramie, and in other localities represents the erosional interval between the Lance and Laramie wherever the two are in contact as seen by Dr. Knowlton and the writer on the North Platte River near the mouth of Medicine Bow River in Wyoming. It marks also the greater stratigraphic hiatus noted in all sections made up to the present time in Montana where the Laramie is absent; and where either the Lance or the Judith River is in contact with the Fox Hills or where this also is absent with the Pierre, all of these conditions are shown graphically in this section. The sections in the Dakotas are not given, but there, as already stated, the Lance is sometimes in direct contact with the Pierre, as in the section given for Willow Creek, Mont., or with the FoxHills beds, the thickness of which varies according to the amount that has been removed by erosion. This need only be referred to here, as the whole subject has been thoroughly treated by Dr. Knowlton in his two papers on the stratigraphic position of the Lance formation.[1] It is necessary to state here only that the writer is in perfect agreement with Dr. Knowlton[2] as to the position of this unconformity and its being the place at which to draw the line between the Cretaceous and Tertiary, and further, to reiterate that the Judith River formation is the direct equivalent of the Lance formation, not only from its paleontological contents, as will be shown later, but also from its stratigraphic position as shown in the section given above.

[1] *Proc. Wash. Acad. Sci.*, XI (1909), 179–238; *Jour. Geol.*, XIX, No. 4 (May-June, 1911), pp. 358–76.

[2] *Jour. Geol.*, XIX, No. 4 (May-June, 1911), p. 376.

SOME TRIASSIC FOSSILS FROM SOUTHEASTERN ALASKA[1]

WALLACE W. ATWOOD

On the north shore of Hamilton Bay, a small re-entrant on the northwest coast of Kupreanof Island, there are rock exposures which have yielded certain Triassic fossils that may prove to be of special value in paleontologic studies.

From reports prepared by F. E. and C. W. Wright, Spencer Brooks, Kindle, and some others, it is evident that the more widespread geologic formations of southeastern Alaska outcrop in roughly parallel north-south belts; that the formations consist, in part of igneous rocks, in part of sedimentary rocks, and in part of metamorphic rocks; that most of the formations have suffered from intense deformation; that numerous intrusions of igneous rocks have occurred; and that the structural relations are exceedingly complex.

The formations included in this complex of older rocks vary in age from early Paleozoic to Triassic. They border and nearly surround the Tertiary coal basins that have thus far been located in this portion of Alaska. Detailed description of these formations as they appear at various localities may be found in the reports of the Alaskan Division of the United States Geological Survey, referred to above.

At Hamilton Bay the older rocks include some of Paleozoic age and some that are of Triassic age. They include limestones, argillites, limestone conglomerates, shales, and sandstones. Associated with these beds there is considerable basalt of a much younger age. The sedimentary beds are highly inclined and are a portion of a closely folded series of strata. They outcrop on the north shore of Hamilton Bay, and there form the northern limit of the area underlain by the Tertiary coal-bearing series.

[1] Published by permission of the Director of the United States Geological Survey.

The limestone conglomerate in the midst of this series, outcropping at the North, near the entrance to Hamilton Bay, is a peculiar formation in that there are huge angular blocks of limestone in it associated with bowlders ranging from one to three feet in diameter. The conglomerate formation is at least 100 feet thick, and may represent an important structural division line in the Mesozoic section.

The fossil collections secured from these older formations have been examined and reported upon by Dr. T. W. Stanton, as follows:

Collection No. 4819—North side of Hamilton Bay.
Pseudomonotis subcircularis (Gabb).
Horizon, Triassic.

Collection No. 4820—Hamilton Bay, North side, a few feet below No. 4819.
Pseudomonotis subcircularis (Gabb).
Numerous immature examples of this species.
Horizon, Triassic.

Collection No. 4821—North side of Hamilton Bay from bowlder in limestone conglomerate.
Rhynchonella. 2 or 3 species.
Spiriferina? sp.

The Rhynchonellas are of Mesozoic type, but the species listed as "*Spiriferina?*" may be a Spirifer, as punctuate structure has not been detected in it.

Collection No. 4822—From another bowlder in conglomerate at same place as No. 4821.
Rhynchonella sp. same as No. 4821.
Pecten sp.
Pleuromya? sp.
Several other undetermined pelecypods.
Trachyceras? sp.
Another undetermined ammonite genus.

This lot, like No. 4821 from the same conglomerate, seems to be of Triassic age. This determination is based on the character of two fragments of ammonite in No. 4822, the character of the Rhynchonellas of which one species is identical in both lots, and the absence of characteristic Paleozoic types.

According to Mr. Atwood's determination, this conglomerate is stratigraphically between the horizons of lots 4819 and 4823,

both of which are definitely determined to be Triassic. This would suggest that Nos. 4821 and 4822 may have come from concretions rather than bowlders, and that the conglomerate has no very great geological significance.

Collection No. 4823—North side of Hamilton Bay.
Halobia superba Mojsisovics?
Ceratites? sp.
Horizon, Triassic.

The pre-Tertiary formations appear to extend northward and northeastward through Kupreanof Island, but no further field-work was done in this locality on the older formations by the present writer.

PRELIMINARY NOTES ON SOME IGNEOUS ROCKS OF JAPAN. VI[1]

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VI. QUARTZ-SYENITE AND COMENDITE FROM THE OKI ISLANDS

Introduction.—Our geological knowledge of the Oki Islands is derived in the first place from the late Dr. T. Harada,[2] Mr. B. Minari,[3] and others, and subsequently from the more detailed work of Mr. M. Yamakami.[4] The last author's report and geological map were published in 1896 by the Imperial Geological Survey of Japan, and many rock-specimens collected by him are preserved in the Survey collection. Among them, I have found some interesting alkalic varieties, many of which have not yet been described in Japan; and their occurrence in our country, especially near the coast of the sea of Japan, is very interesting from a petrological point of view. In the summer of 1911, I had an opportunity to visit the islands and to make a collection of several varieties of these interesting rocks. The following description is a preliminary account of the petrological observations made on my journey, and of the quartz-syenite and comendite, the most interesting rocks that I collected.

For the chemical analyses of these rocks, made in the laboratory of the Imperial Geological Survey of Japan, I am greatly indebted to Mr. K. Yokoyama, and my sincere thanks are due to Professor B. Koto, for advice and assistance in the study of the rocks.

[1] Published by permission of the Director of the Imperial Geological Survey of Japan.

[2] T. Harada, *Versuch einer geotectonischen Gliederung der japanischen Inseln*, Imp. Geol. Survey, Japan, 1888; T. Harada, *Die japanischen Inseln*, Imp. Geol. Survey, Japan, 1890.

[3] B. Minari, Explanatory Text to the Agronomic Map of Izumo, Iwami, and Oki Provinces (in Japanese), Imp. Geol. Survey, Japan, 1895.

[4] M. Yamakami, Explanatory Text to the Special Geological Map of the Section Oki (in Japanese), Imp. Geol. Survey, Japan, 1896.

Morphological sketch of the Oki Islands.—The Oki Islands, lying within 132° 56′–133° 22′ E. long. and 35° 56′–36° 20′ N. lat., are off the coast of Izumo, the northwestern province of Honshû, at a distance of about 65 kilometers. There are four main islands, in two groups. One large island called Dōgo is situated to the northwest, and is separated by a strait 12 kilometers wide from the other three smaller ones—Chiburi-shima, Nishino-shima, and Nakano-shima, together known as Dōzen. There are also 180 islets and rocks included under the name of the Oki Islands. The total land-area is about 351 square kilometers.

The coast line of Dōgo is rather regular, and its shape is roughly circular, indented by the bay of Saigō on the southeast and by the bay of Fuku-ura on the northwest. Many other smaller narrow inlets occur mostly on the southern coast. The coast line of Dōzen, however, is irregular and is detached into three islands by narrow channels called Ōguchi, Akanadaseto, and Nakaiguchi. These islands are arranged in a triangular position on the arc of a circle.

Dōgo has a length of about 21 kilometers from south to north and a little shorter breadth from east to west. Its area is about 245.6 square kilometers, and the coast, in great part, ends abruptly against the sea, with elevations varying from 30 meters to 100 meters. The island is mountainous and morphologically divisible into two parts, the western and eastern districts (Fig. 1), separated by a watershed trending nearly north and south through the middle of the island. The western region consists of gently sloping ridges (Fig. 1), composed of rhyolite flows, averaging 300 meters in altitude. These flows have been eroded to deep and narrow valleys diverging toward the west and southwest from two isolated peaks, called Ōmine (666 m.) and Yoko-o-yama (568 m.), which are situated on the watershed. It is evident that the region was formerly covered by almost horizontal rhyolite flows. The eastern district is characterized by ragged peaks and isolated knolls, composed of several kinds of rocks. The highest point on the conical mountain of trachydolerites, named Daimanji (Fig. 1), is 646 meters in altitude. The south and east ridges descend gradually, but the mountains to the north and west have precipitous slopes and are very irregular.

The most striking physical feature of Dōzen is the circular arrangement of the three main islands. The largest island, Nishino-shima (55.23 sq. km.), lies on the northwest of the group; the smaller one, Nakano-shima (35.20 sq. km.), on the east; and the smallest, Chiburi-shima (14.82 sq. km.), on the south. An inland sea with an area of about 51.24 square kilometers is inclosed by the three islands. The most prominent peak, called Takuhi-yama (Fig. 2), 525 meters in height, is situated south of the middle part of Nishino-shima. The sea coast facing the ocean ends abruptly, as is the case at Dōgo, and the slope of the islands is steeper toward the inner side than toward the outer. Dr. T. Harada compared the form of Dōzen with that of Santorin in the Mediterranean.

FIG. 1.—Dōgo as seen from the south

Geological sketch of the Oki Islands.—In order to give a general idea of the structure of the Oki Islands, their geological features will be described briefly. The geological formations of the islands, in the order of their age from younger to older, are as follows:

1. Alluvium.
2. Trachydolerites and basalts.
3. Diluvium (?).
4. Trachytes.
5. Trachyandesites and trachydolerites.
6. Trachytic rhyolites.
7. Greenish trachyandesites.
8. Soda-rhyolites.
9. Schistose granites and quartz-syenites.
10. Andesites.
11. Tertiary strata.

The islands consist mainly of volcanic rocks, which were erupted at several times, probably from the middle of the Tertiary

to the beginning of the Diluvium. Besides these extrusive rocks, there are intruded masses of granites, quartz-syenites and their allied porphyries, occurring in a limited area. It is highly probable that all these igneous rocks are younger than the bottom beds of the Tertiary, which make up the base of the islands.

At Dōgo, the Tertiary formation is met with in the southwestern and northeastern sea-cliffs overlaid by lava flows, and in the middle of the island, where the elevation is about 300 meters above the sea-level. It consists of tuffs, conglomerates, sandstones, and shales, in which deposit plant fossils are preserved. The formation is intruded by andesite sills and by schistose granites and their allied porphyries. It is folded and faulted, and its strikes and dips are variable in places, but the general dip is gentle.

At Dōzen, the Tertiary formation occurs in a small area and is free from andesite sills, so far as the writer's observation goes. But it is intruded by quartz-syenite and its apophyses, and at the place of contact, metamorphosed sandstone with abundant brown mica is exposed.

The age of the formation is considered to be Miocene, corresponding to that of the formation along the northwestern coast of Honshū.

The Diluvium is exposed near Tōgō, a small village in Dōgo. It consists of gravels and blocks of trachydolerites and trachytic rhyolites, and is overlaid by the younger trachydolerite flow. The outcrop is clearly seen at a new cutting, a little south of Tōgō. The formation seems to have been locally deposited in a lake, which now forms the bay of Saigō.

The Alluvium is river deposit, seen in a limited area along valleys. The description of

FIG. 2.—Dōzen as seen from the southeast

the geological relations of the igneous rocks[1] will be given with the petrographical notes of each kind of rock. However, some striking geological features may be mentioned. Enormous quantities of trachydolerites and trachyandesites were erupted near the end of the igneous activity in the region, and Dōzen was mainly composed of these rocks. Their eruptions seem to have occurred at several localities. After some interval of time there was a depression of the middle of the land which formed the inland sea already described. This movement fractured the ground greatly and gave rise to the eruption of trachytes. The rocks occur as flows and dikes; the flows form most prominently Takuhi-yama, and the dikes occur in very remarkable radial arrangement having Takuhi-yama as an approximate center, traversing trachydolerites, trachyandesites, and the Tertiary formation; but no dike was seen cutting the syenite mass. The occurrence of these dikes is analogous to that of the basic dikes in Rum, Scotland, described by Harker[2] and to that of the basaltic and trachytic dikes in the Highwood mountain, Montana, described by Pirsson;[3] though the petrographical character of the rocks and the number of the dikes are not the same.

QUARTZ-SYENITE

Field observation.—The rock is found in a small mass, only, at the northeastern foot of Takuhi-yama at Dōzen. It occurs intruded in the Tertiary formation and is covered by glassy trachytes which build up Takuhi-yama. Its contact action on the Tertiary rocks is clearly seen, and the metamorphosed shaly sandstone is permeated by a brown mica as a contact mineral. The endomorphic effect is not so pronounced as that observed in other countries where this rock type has been described by several authors. The texture becomes gradually fine-grained and inconspicuously porphyritic by the development of feldspar 1 cm. in average length. Hornblende, which occurs as an essential mineral in the main mass,

[1] The petrographical notes on several kinds of rocks from the islands are not described in this paper. They will be published in the report of the Imperial Geological Survey of Japan.

[2] Harker, *Memoirs of the Geological Survey, Scotland*, 1908, p. 143.

[3] Pirsson, *Bulletin No. 237, U.S. Geol. Surv.*, 1905, p. 20.

is almost entirely replaced by biotite in the fine-grained part. If the Tertiary formation, through which the syenite intrudes, proves to be Miocene as considered now, the syenite will be probably the youngest rock of this kind which has ever been described.

Megascopic character.—It is medium-grained, evenly granular, and almost compact, though miarolitic cavities are present. On a freshly fractured surface, the color is light gray with somewhat waxy luster. The rock consists mainly of feldspar, which is light gray, due to clouded, minute inclusions; and, in some crystals, a faint blue shiller is recognizable. Close examination shows certain feldspars developed with a more or less idiomorphic and thick tabular habit. Black hornblende occurs in moderate quantity, scattered through the feldspathic mass. Its form is irregular, but the general shape is prismoid with an average length of 3 mm. Biotite is quite subordinate in amount, and quartz is scarcely detected with a lens.

Microscopical character.—The constituent minerals present in the rock specimen used for a chemical analysis are quartz, alkali feldspar, plagioclase, hornblende, biotite, diopside, olivine, apatite, zircon, ilmenite, and magnetite; besides zeolites in miarolitic cavities. The amounts of diopside and olivine are variable even in specimens taken from very near one another. A thin section shows the presence of allanite. The rock consists essentially of feldspar with hornblende; and the other minerals, with the exception of allanite, are also constant ingredients, though their quantities are subordinate and variable. The texture, for the most part, is granitoid, but there are some peculiarities of micrographic intergrowth of feldspar and quartz and of miarolitic cavities.

The feldspars are mostly alkalic (orthoclase, microperthite, and cryptoperthite), but plagioclase is not rare. The latter mineral is represented by oligoclase and albite, which, besides perthite, is also found as the border of the alkali feldspar. The alkali feldspars are tabular, parallel to (010), and are variable in shape, some of them being irregularly contoured and others rather euhedral. They are clouded with dusty particles and frequently show the zonal structure due to chemical differences. The outer shell is usually thin and clear, in strong contrast to the clouded inner part. The former

show slightly higher refraction and birefringence than the latter. The extinction angle of the shell is $+10°$ on a section nearly parallel to (010), while the inner part shows $+7°$ on the same section. From these characters, the outer material must be referred to a variety of anorthoclase with especially high content of soda. Inclusions are plagioclase, sharply defined apatite, a few crystals of zircon, magnetite, and quartz. The last mineral appears micrographically intergrown in the peripheral part of the feldspar. No microcline structure is observed. The oligoclases usually occur in prismatic form and are, in many instances, included in the alkali feldspar. They show distinct polysynthetic lamellae and are clearer, owing to fewer inclusions, than those in the alkali feldspar. They vary in composition within a limited range, judging from their indices of refraction. Generally the refractions are slightly higher than those of quartz and Canada balsam and the maximum symmetrical extinction angle of a calcic variety exceeds 17°.

The hornblende is mostly greenish-brown, associated with a bluish-green variety. Its form is irregular in general; sometimes more or less idiomorphic in elongated or short prismatic form. Cross-sections exhibit the characteristic cleavage and rhombic outline, or sometimes six-sided section elongated along the axis *b*, having the first pinacoid strongly developed and with the unit prism subordinate. The bluish-green variety occurs as fringes or borders, and as inclusions in the brown, and as an individual of quite irregular shape in very rare instances. In the first instance the green variety does not entirely inclose the brown, and in many instances it occurs on the terminal faces of the brown crystal. These two varieties exhibit almost no differences in optical orientation. They are strongly pleochroic: *X*, light yellow; *Y*, dark brownish-yellow; *Z*, greenish-brown to olive-green; absorption $Y>Z>X$, on the greenish-brown variety, and *X*, light yellow; *Y*, yellowish-green; *Z*, bluish-green; absorption $Z>Y>X$, on the bluish-green variety. They extinguish in nearly the same position and the angle between *Z* and *c* on (010) is from 26° to 28° in the obtuse angle *B*. From these properties, the hornblende seems to be barkevikite near katophorite or hastingsite, but it is not like it in the larger optical angle (?) and the higher birefringence.

Quartz is present in small amount as shown by the chemical analysis, but it is sufficient to characterize the rock as quartz-bearing syenite. It occurs interstitially, or intergrown micrographically, with the alkali feldspar, and frequently as an infiltration in miarolitic cavities with zeolite. In the last case, it often shows distinct euhedral outline.

Biotite is sparingly present, and usually occurs associated with hornblende. It is optically negative, and the plane of the optic axes lies in the plane of symmetry. The optical angle measured is $2E=36^\circ 23'$. The pleochroism is strong: X, brownish-yellow; Y, brown with violet tinge; Z, dark reddish-brown; and absorption, $Z>Y>X$. Magnetite and apatite are included in it.

The diopside shows an irregular form and is colorless or pale violet, being slightly pleochroic. Its quantity is variable and it shows a tendency to replace hornblende. Olivine occurs in more or less automorphic outline, and is quite fresh. It is almost free from inclusions with the exception of a few minute crystals of magnetite and apatite. The ilmenite and magnetite are present in association with each other. The former is in irregular form and is characterized by the decomposed product, leucoxene. Apatite occurs conspicuously in elongated prismatic form. It is comparatively abundant.

The mineral described here as allanite is not exactly determinable, owing to its rare occurrence and deep color, in some instances being almost opaque. It is strongly pleochroic from deep reddish-brown to opaque. In some respects, it resembles aenigmatite or rhönite. Its form is long prismatic with irregular terminations. Zonal structure is not recognizable, and cleavage is also indeterminable. One section observed is cut nearly perpendicular to an optic axis, its cross-bar appearing in the middle of the field. The case is very similar to that of the allanite-like mineral in the Mt. Belknap syenite, described by Pirsson and Washington. The characters of the mineral will be determined after further examination of more thin sections.

Chemical character.—The analysis of the rock, collected from the eastern foot of Takuhi-yama, Ezirigasaki, Kuroki-mura, Dōzen, was made by K. Yokoyama in the laboratory of the Survey. It is given

in column A in the following table. Compared with foreign rocks, the rock from Oki has a close resemblance to the akerite-porphyry, described by Brögger;[1] the augite-syenite, described by Cushing;[2] the quartz-syenite, described by Pirsson;[3] and the syenite, described by Pirsson and Washington.[4] It differs from the pulaskite from Fourche Mountain, described by Williams[5] and by Washington[6] respectively, in having less alumina, less alkalies, and more iron oxides. These relationships are shown in the following table:

	A	B	C	D	E	F	G
SiO_2	61.83	62.60	63.45	65.54	60.75	60.25	60.03
Al_2O_3	17.08	18.07	18.31	17.82	19.68	20.40	20.76
Fe_2O_3	2.14	2.28	0.42	0.74	1.54	1.74	4.01
FeO	2.71	2.25	3.56	1.15	2.98	1.88	0.75
MgO	0.89	1.16	0.35	0.98	0.81	1.04	0.80
CaO	2.24	2.27	2.93	1.92	2.29	2.00	2.62
Na_2O	4.93	5.45	5.06	5.55	4.89	6.30	5.96
K_2O	5.37	5.22	5.15	5.58	5.90	6.07	5.48
H_2O+	1.60*	0.50	0.30	0.54	0.08	0.23	0.53
H_2O-	....	....	....	....	0.24	0.10	0.06
TiO_2	0.30	....	0.07	0.11	0.63	0.14	....
ZrO_2	....	....	....	....	...a	trace	....
P_2O_5	0.35	....	trace	....	trace	0.15	0.07
SO_3	....	....	....	....	....	0.13	....
MnO	0.12	....	none	trace	trace	trace	trace
BaO	....	....	0.13	....	....	....	....
Li_2O	....	....	....	trace	....	....	....
Total	99.56	99.84	99.73	99.92	99.79	100.47	101.07

* Loss on ignition.

A. Quartz-syenite from the eastern foot of Takuhi-yama, Dôzen, Oki. K. Yokoyama, analyst.

B. Åkerite-porphyry from Ullernas, Norway. G. Forsberg, analyst.

C. Augite-syenite from Loon Lake, Franklin County, N.Y. E. W. Morley, analyst.

D. Quartz-syenite from Highwood Peak, Highwood Mountain, Mont. Pirsson and Michell, analysts.

E. Syenite from the western slope of Mt. Belknap, N.H. H. S. Washington, analyst.

F. Pulaskite from Fourche Mountain, near Little Mountain, Ark. H. S. Washington, analyst.

G. Pulaskite from Fourche Mountain, near Little Mountain, Ark. R. N. Brackett, analyst.

[1] Brögger, *Zeitschrift für Krystallographie*, XVI (1890), 49.

[2] Cushing, *Bulletin of the Geol. Society of America*, X (1899), 183.

[3] Pirsson, *Bulletin No. 237, U.S. Geol. Surv.*, 1905, p. 63.

[4] Pirsson and Washington, *American Journal of Science*, XXII (1906), 446.

[5] Williams, *Ann. Rep. of the Geol. Surv., Arkansas*, II (1890), 70.

[6] Washington, *Journal of Geology*, IX (1899), 1901.

Norms, calculated from the analyses, are as follows:

	A	B	C	D	E	F	G
Quartz	6.1	3.2	5.2	6.1	2.0	....	....
Orthoclase	31.7	31.1	31.1	32.8	35.0	36.1	32.8
Albite	41.9	46.6	42.4	47.2	41.4	41.0	45.6
Anorthite	8.6	8.9	11.7	7.2	11.4	9.2	13.3
Corundum	....	....	....	....	1.0	....	....
Nepheline	....	....	....	....	....	6.2	2.6
Diopside	....	2.1	2.2	1.9	....	0.8	....
Hypersthene	5.8	4.2	6.0	3.1	5.3	....	....
Olivine	....	....	....	....	....	3.1	1.4
Magnetite	3.0	3.2	0.7	1.2	2.1	2.6	2.6
Hematite	....	....	....	....	....	....	3.2
Ilmenite	0.6	....	....	....	1.2	0.3	....
Apatite	1.0	....	....	....	....	....	....

The ratios of the rock from Oki are as follows:

$$\frac{Sal}{Fem} \ldots\ldots 8.49$$

$$\frac{Q}{F} \ldots\ldots 0.07$$

$$\frac{K_2O' + Na_2O'}{CaO'} \ldots\ldots 4.42$$

$$\frac{K_2O'}{Na_2O'} \ldots\ldots 0.71$$

By the Quantitative System, the rock may be classified as pulaskose, near lauvikose.

As will be seen from the above description, the present rock is chemically close to acidic åkerite, that is, pyroxene-syenite, but it has mineralogically and chemically a close relation to the syenite from Belknap Mountain, New Hampshire. The petrographical characters of the rock show also some relation to normarkite on the one hand and to umptekite on the other. So it is concluded that the Oki rock is characterized, by mineralogical and chemical properties intermediate with respect to nordmarkite, umptekite and åkerite, though it is nearer to the last type.

THE EFFECT OF IGNEOUS INTRUSIONS ON THE ACCUMULATION OF OIL IN NORTH-EASTERN MEXICO

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The region where the occurrences herein noted were observed comprises the portion of the Mexican coastal plain between the Panuco and Tuxpan rivers in the northern part of the state of Vera Cruz.

The formations involved in the geology of this area are of Cretaceous and Tertiary age, with unimportant Quaternary deposits near the coast. For convenience, they will be separated according to lithology into three divisions; the lower of which is made up of several thousand feet of limestones overlain by a series of alternating limestones and shales, the whole of Cretaceous age; the middle, of uniform shales and marls with a total thickness of about 3,000 feet, of upper Cretaceous-Eocene age; and the upper, of Tertiary sands, clays, limestones, and conglomerates, having an aggregate thickness of about 700 feet.

The marked characteristic of the geology of this region is the large number and magnitude of the volcanic intrusions, the remnants of which are represented in places by isolated basaltic cones, breaking the monotony of the coastal plain. The volcanic activity is more pronounced in the southern portion of the area, attaining its greatest development in the Otontepec range, an irregular basaltic mass about 2,000 feet high. The location of many of the intrusions was probably controlled by well-defined fault lines, and cross-faulting or any decided weakness of the underlying basement may also have played an important part in their distribution. The intrusions occurred during late Tertiary or possibly early Quaternary times, and consist of basalt accompanied in places by volcanic ash and conglomerate. Most of the surface indications of oil are closely associated with the basalts and hundreds of such

phenomena occur throughout the area examined. Among the localities where oil seepages are abundant might be mentioned La Pez, La Dicha, Chijol, and Santa Margarita, near the Eban field; San Geronimo, La Merced, Rancho Abajo, Monte Alto, and Los Higueros, between the famous Dos Bocas and Casiano; Casiano, Cervantes, Tres Hermanos, Tinaja, Ojo de Brea, Chapopotillo, Monte Grande, Moralillo, Cerro Azul, Juan Felipe, Las Borrachas, Piedra Labrada, and Cerro Viejo, between the producing fields of Casiano and Potrero del Llano.

The intimate association of the volcanic intrusions and some of the producing fields is so apparent as to be unquestionable, and the problems in this connection relate chiefly to the effect of the basalt on the structure and texture of the intruded beds which resulted in their becoming capable of storing large amounts of oil under tremendous gas pressure.

The general conception of the form of these intrusions is that of a more or less irregular cone, in a normal position, the vertex of which may or may not reach the surface. Were these conditions fulfilled in the Mexican coastal plain, a well drilled near an outcrop of basalt would eventually strike the side of the cone and thus preclude further progress. This assumption is certainly not corroborated by actual experience in the fields, as many of the best producers are located in very close proximity to intrusions, and in some cases the basalt has been penetrated for several feet and the well continued to the oil reservoirs below.

In order to account for these discrepancies the writer performed a rather crude experiment, as a result of which were obtained some interesting data which seem to throw considerable light on the behavior of the intrusions and their effect on the intruded beds. Assuming the thickness of the uniform Cretaceous-Eocene shales as 3,000 feet, and that of the average intrusion as 1,000 feet, it was thought that the effect of the latter as it penetrated through the uniform series of shales would in some ways be parallel to that of a nail driven through an unbound book of a thickness three times as great as the diameter of the nail. The experiment was tried while the book was resting, first on a board, then on a folded blanket, and again on the open end of an inch pipe, and the

results obtained were remarkably uniform. It was found that the leaves first penetrated were distorted only within a comparatively small radius, and that the zone of distortion increased toward the bottom in a more or less uniform ratio. A horizontal plan showed that in order to take care of the buckling near the nail, the first leaves had been torn at right angles and that the number of fissures naturally decreased as the zone of bending increased. It was also noticed that the fracturing and folding of any leaf around and near the nail was to a great extent controlled by the location and nature of displacement in the leaves immediately under, and this resulted in the formation of zones of dislocation along approximately vertical planes, most of which were closed before reaching the surface owing to the lesser number of fractures in the leaves last penetrated.

From these experimental observations and the results of actual experience in the developed portions of the fields, the following tentative conclusions have been drawn:

The thickness of the basalt intrusions as they pass through the Cretaceous-Eocene shales toward the surface increases roughly in a uniform ratio.

The horizontal zone of folding of the shales around the intrusions increases toward the surface.

The horizontal zone of fracturing varies with that of folding, but the number of fractures is greater in the deeper beds.

The fractures seem to occur along roughly vertical planes, thus forming deep well-like channels.

These vertical holes, partially filled with basalt and shale, could be effectively capped before reaching the surface, owing to the fewer number of fractures in the higher beds and the increasing cross-section of the intrusion toward the surface.

Before discussing the relation of the intrusions to the accumulation of the oil and gas, it is thought advisable to summarize certain views regarding the origin of the oil in this region:

For obvious reasons, the oil did not originate in the 700 feet of sandy limestones, conglomerates, and clays of Tertiary age, the remains of which are now exposed in patches here and there.

If the 3,000 feet of Cretaceous-Eocene shales were the source of the oil, they would show a more or less bituminous character

throughout, or at least be of such an organic nature as to account for their furnishing the great quantities of oil in these fields. The shales which are exposed over nearly the whole area, however,

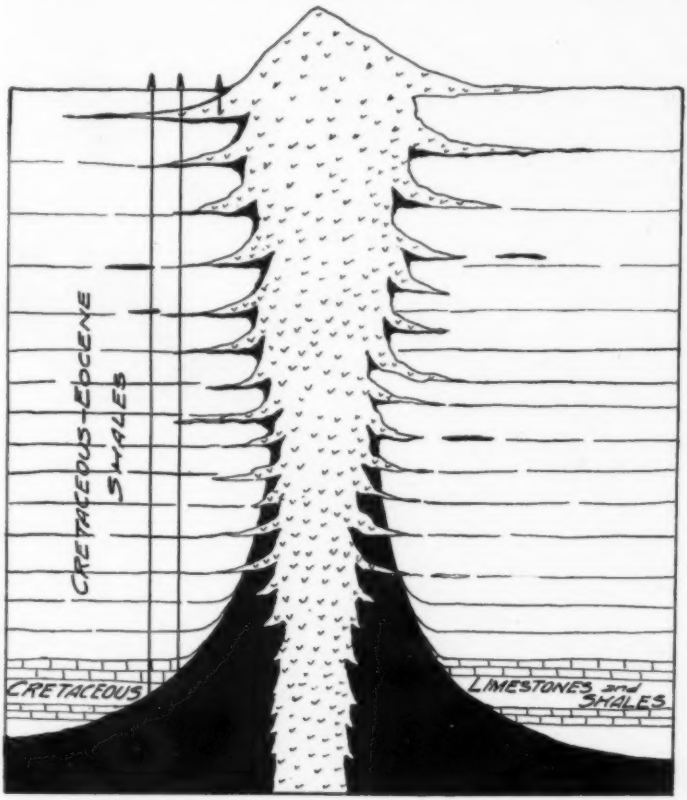

FIG. 1.—Hypothetical section showing basalt intrusion reaching the surface and resultant conditions in the intruded beds, conducive to the accumulation of oil. The two deep wells tapped the oil zone after penetrating the basalt, while the well nearest to the cone was abandoned in the basalt.

show signs of oil only near intrusions, and in all the exposures examined were of a uniform inorganic nature.

The migration of oil in impervious shales of this nature takes

place mainly along bedding planes, and any barrier, such as the basalt intrusions, cutting across the planes of migration, will effectively intercept the flow. If resultant conditions are favorable, the vicinity of the barrier will become an ideal zone of concentra-

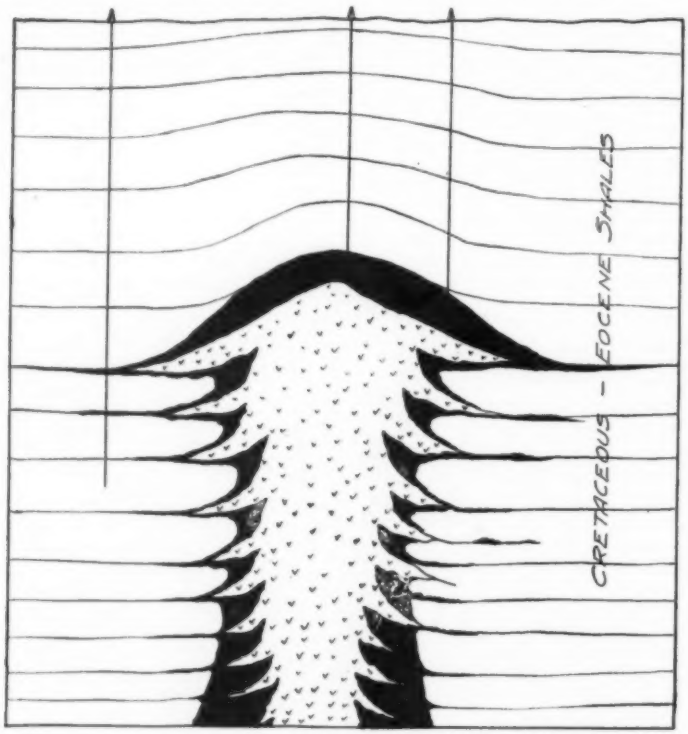

FIG. 2.—Hypothetical section of a basalt intrusion penetrating the Cretaceous-Eocene shales to a point below the surface, illustrating how a deep well might encounter only "showings" of oil, and two neighboring shallower wells obtain a fair production in the shales.

tion for the flow of all the lateral channels penetrated, and, owing to the large drainage area contributing to the accumulation, this will be comparatively large, even if the amount of organic matter in the shales is small. In other words, the basalts which intrude

the Cretaceous-Eocene shales certainly afford one of the most effective means to concentrate whatever hydrocarbons might have been disseminated throughout these beds.

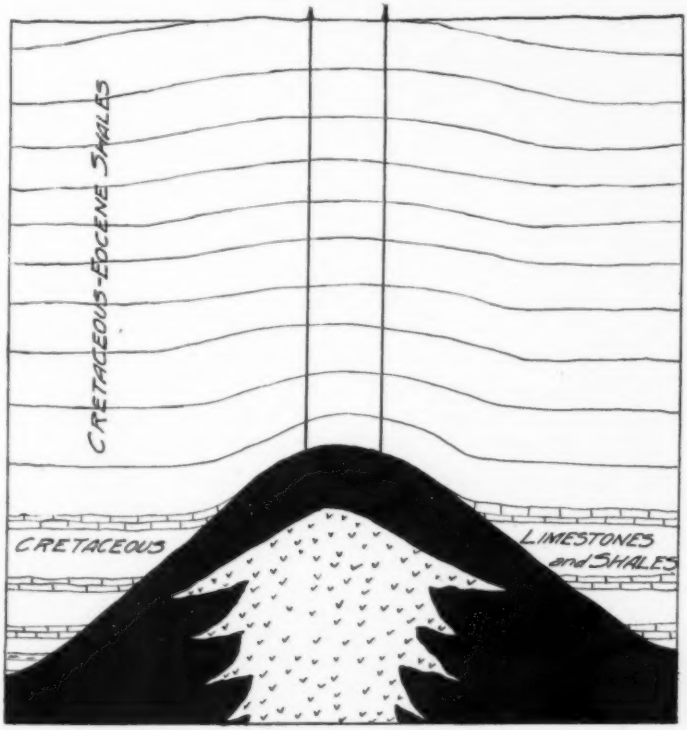

FIG. 3.—Hypothetical section of basalt intrusion penetrating the series of Cretaceous limestones and shales without disturbing the Cretaceous-Eocene shales, and giving rise to a dome of fractured and porous material, effectively covered with an impervious cap-rock. The large production of some of the Mexican gushers can readily be accounted for on this hypothesis.

Finally, it is apparent that if the Cretaceous limestones yielded the oil, it must have been before the event which changed them to their present compact and rather crystalline nature, and it is probable that such a condensation of the oil was coincident with

the change in the nature of the beds. The oil could then have migrated along fissures toward the upper beds, aided by the action of water, and collected in the upper Cretaceous limestones and shales, to be concentrated in the favorable zones created by the igneous intrusions. Such migration had necessarily to take place after the deposition of the Cretaceous-Eocene cap-rock.

The accompanying figures summarize graphically the writer's conception of the effects of the igneous intrusions on the accumulation of oil in northeastern Mexico. Fig. 1 shows an intrusion which reaches the surface. In this case some oil may percolate through the shales, forming seepages near the basalt outcrop, and wells of varying productiveness may be located at comparatively short distances from the outcrop. If the intrusions penetrated the Cretaceous-Eocene shales to a point below the surface (Fig. 2), these would be arched above the basalt, thus affording a dome-shaped reservoir in the shales, which might prove commercially productive for a comparatively short time. If, however, the intrusions perforated only a portion of the series of limestones and shales at the top of the Cretaceous limestones (Fig. 3), the resultant dome of porous and fractured material, capped by a thick cover of impervious shales, would form an ideal reservoir, which, if tapped, would readily account for the tremendous gushers characteristic of this region. Any and all of these conditions may exist, and it is probable that, with certain modifications, all do occur at one point or another in the portion of the Mexican coastal plain herein mentioned.

August 5, 1912

EDITORIAL

THE WILLIAMS PHOTOGRAPHIC PROCESS

It gives us pleasure to publish the following letter of Roger H. Williams announcing the dedication to the free use of scientists of the Williams patented process for preparing fossils and other objects for photographing. Paleontologists in particular will appreciate this generous action and will be deeply gratified that the original wish of the inventor of the process, Dr. Henry S. Williams, and the purpose of his son, the proprietor of the patent, are thus consummated. This is but one of many valued contributions to paleontolgy and geology by Dr. Williams which have placed his colleagues under obligations and have won their high esteem.

T. C. C.

September 12, 1912

Editor of "Journal of Geology":

DEAR SIR: It may be of interest to your readers to know that as of July 1, 1912, there has been dedicated to the free use of science and scientists the patented process for photographic illustrations (U.S. Pat. No. 640,060), owned by the undersigned and known among paleontologists, who found it especially useful in specimen work, as the "Williams Process."

In brief, it consists in the deposition by sublimation on the object to be photographed of an extremely tenuous monochrome film for the purpose of obviating the reflection, refraction, and distorted shadow values common in ordinary photography of certain classes of objects.

It has been a matter of great regret to the writer that a long-continued and expensive investigation, arising out of an entirely legitimate difference as to the scope and validity of the patent, has delayed until now the fulfilment of the original intention of the writer to make this dedication so soon as the expenses incurred in perfecting and establishing the patent should have been secured by the moderate royalties hitherto charged. The outcome of the controversy has entirely justified the writer's position—the opinion of the opposing experts conclusively confirming the fundamental character of the invention.

As one interested in science, the writer would have been pleased if his means had permitted the assumption of all the expenses of this patent without thought

of recoupment, and is heartily sorry that there are those who felt that the failure to do so is culpable. If it is so, I can only plead that it is so in violation of no code with which I am familiar.

In view of the fact that the invention was originally made by my honored father, Dr. Henry Shaler Williams, of Cornell University, it is most desirable that certain facts be stated for the benefit of those who may in the past have been under a misapprehension as to his relation to the patent. Almost immediately after being granted, the patent was transferred from him to me in good faith and in consideration of the assumption of debts incurred in its development. My father's wish always has been that the process should be made freely available to science gratis, and I promised him it should be as soon as its financial situation could be cleared up. It has never yielded a cent of profit to Henry Shaler Williams, nor was it taken over or ever handled with the idea of exploiting science or making commerce of its needs. This cannot be stated too strongly. With the long-drawn-out controversy referred to my father has not only had nothing to do, but has repeatedly endeavored to induce me to abandon it.

Therefore the blame in the matter, if blame there be, is entirely mine and I cheerfully shoulder it; but he should be given complete exoneration from any such charge. Those who have been disposed to think critically of Dr. Williams in connection with the patent have been doing a great and unwarranted injustice to a high-principled man, whose character and whose long and disinterested devotion to science should have made it unnecessary to break the silence he has long maintained, as I now do, without his knowledge, to right a wrong; and, as I sincerely hope, to remove completely any ground for misgiving on the part of any one of his many distinguished friends toward a loyal and worthy colleague.

ROGER H. WILLIAMS

Reviews

Geology and Mineral Resources of Parts of the Alaska Peninsula. By Wallace W. Atwood. Bull. U.S. Geol. Surv. No. 467.

All available material bearing upon the geology and mineral resources of the Alaska Peninsula have been compiled and presented in this bulletin, and a considerable body of new material secured during the season of 1908 by Wallace W. Atwood and H. M. Eakin while investigating the coal fields of the Alaska Peninsula is here presented for the first time.

A large general map of the general geology of the peninsula and special detail maps of the Herendeen Bay and Unga Island region, and of the Chignik Bay region, are embodied in the report.

The geologic formations exposed in the peninsula range in age from Upper Triassic to the present. The Herendeen section, which has been worked in detail, includes representatives of the Upper Jurassic, Lower and Upper Cretaceous, Eocene, Miocene, Pleistocene, and Recent. Associated with the clastic sediments of this region there are some limestones and vast quantities of volcanic material, some of which appear to be of late Eocene age and some post-Miocene. There are active volcanoes in the region today adding to the pyroclastic rocks of the region.

The available coal measures in the Herendeen Bay region are in the Upper Cretaceous formation. A poor grade of coal or lignite is also found in rocks of Eocene age.

The Unga Island coal field located at Coal Harbor contains lignitic coal of Eocene age.

The Chignik Bay section includes rocks of upper Jurassic age, Upper Cretaceous, Eocene, and later volcanic, glacial, and post-glacial formations. The workable coal in the Chignik Bay field is also found in rocks of Cretaceous age.

Mr. Atwood has included a description of the general geographic and climatic conditions in the Alaska Peninsula, the present status of gold, copper, and coal mining, and a series of suggestions to the prospector.

The report is especially well illustrated with photographic views, numerous structure sections, and topographic sketches, and includes a somewhat full statement of the geomorphology of this portion of Alaska. The field work was carried on under difficult conditions and the report is a welcome addition to the available material on a little-known portion of the continent.

The Inland Lakes of Wisconsin. By EDWARD A. BIRGE and CHAUNCEY JUDAY. Bulletin XXII, Scientific Series No. 7, of the Wisconsin Geological and Natural History Survey.

This report deals with the dissolved gases of the water and their biological significance. Five years have been spent in this investigation. The work was first undertaken and outlined by Mr. Birge, who has kept general oversight over the work throughout the investigation and who has prepared the introduction to the present volume, but Mr. Juday has taken more and more of the responsibility of the investigation and is credited with the preparation of the body of the report.

As stated in the opening chapter, the primary object was to make a general survey of the lakes situated in various parts of Wisconsin in order to ascertain the status of the physical, chemical, and biological conditions which exist in them. Special consideration was given to lakes existing in different portions of the state and under different climatic conditions. The waters were examined for their content of oxygen, carbon dioxide, nitrogen, methane, carbon monoxide, and some other gases, and analyses were made of the mineral content.

The report gives a reasonably full account of the dissolved gases in the waters and sets forth the seasonal variations of these gases, their vertical distribution, the effect of the seasons and the plankton on the quantity and distribution of the gases, but the authors frankly admit that many of the biologic problems associated with their studies have not been solved.

The question why different lakes that are of about equal age, that have the same species of plankton, where temperatures do not differ widely, where the chemistry of the waters is not greatly different, where the planktons have had apparently the same advantages for development, differ so widely in productivity or ability to support a population of plankton, is not solved, and many other problems of a biological and chemical nature have arisen during the investigation which invite further study.

W. W. A.

Atlas photographique des formes du relief terrestre. Selected and prepared for publication by an international Commission appointed at the Ninth International Congress of Geography.

The plan of this atlas involves the preparation of nine volumes each to contain 48 plates, and each plate to be accompanied by a text descriptive of the geologic and physiographic features shown in the view. The

few sample plates which have been issued characterize the work as excellent. These volumes cannot but be of great interest and value to all members of the geologic and geographic professions and also to laymen.

The arrangement of the material in the nine volumes is as follows:

1. Relief features due to weathering and disintegration.
2. Simple features due to stream erosion.
3. Complex features due to stream erosion.
4. Land forms influenced by the nature and composition of rocks.
5. Features influenced by geologic structures.
6. Glaciers and relief features associated with ice action.
7. Relief features due to wind work.
8. Shore-line features.
9. Relief features due to vulcanism.

The Executive Committee of the commission consists of J. Brunhes, E. Chaix, and Emm. de Martonne. The American members of this commission are W. M. Davis and Wallace W. Atwood.

The price of each volume of the series has been placed at Fr. 30, and it is contemplated that 48 plates, the equivalent of one volume, will be issued each year.

W. W. A.

Illinois State Geological Survey. Bulletin No. 16. Urbana, 1910. Pp. 402; pls. 37; figs. 9.

This volume deals chiefly with the oil, coal, lead, and zinc resources of the state, and contains the following papers: "The Administrative Report for 1909," by Frank W. DeWolf, acting director, pp. 11–23; "Elizabeth Sheet of the Lead and Zinc District of Northern Illinois," by G. H. Cox, pp. 24–41; "Oil Resources of Illinois with Special Reference to the Area Outside the Southeastern Fields," by Raymond S. Blatchley, pp. 42–176; "Studies of Illinois Coal," a series of papers consisting of: An Introduction, by F. W. DeWolf, pp. 178–81; "The Illinois Coal Field," by A. Bement, pp. 182–202; "Chemical Composition of Illinois Coal," by S. W. Parr, pp. 203–43; "The Geology and Coal Resources of the West Frankfort Quadrangle," by G. H. Cady, pp. 244–65; "The Geology and Coal Resources of the Herrin Illinois Quadrangle," by T. E. Savage, pp. 266–85; "The Geology and Coal Resources of the Murphysboro Quadrangle," by E. Wesley Shaw, pp. 286–94; "Mine Rescue Work in Illinois," by R. Y. Williams, pp. 295–99; "Diamond Drill Core from Franklin County," Interpretation by Jon Udden, pp. 300–301. The volume contains also a paper on the

"Faunal Succession and the Correlation of the Pre-Devonian of Southern Illinois," by T. E. Savage, pp. 302–41, and a joint paper by Udden and Todd "Structural Materials in Illinois," pp. 342–90.

F. M. H.

Mineral Resources of the United States, 1909. Washington: U.S. Geological Survey, 1911. Part I, "Metals," pp. 617, plate 1; Part II, "Nonmetals," pp. 942.

The usual statistical tables are extended to include 1909. A general increase in production over that of 1908 is shown, but only a few products have recovered to the high values of 1907. Among these is aluminum, which showed in 1909 an increase of 206 per cent over 1908.

Compared witht the figures for production in 1908 only thirteen out of the seventy-four items listed show a decline. Of these platinum shows an increase in total value in spite of a 15 per cent decrease in production. Iron and copper show notable increase, both surpassing in quantity the output for 1907.

Among other changes the following points are of interest:

California shows an increase of 20 per cent in its petroleum output, partly due to the development of the Coalinga field. Colorado shows a general decline in its major products but a slight increase in total value.

Renewed activity in the Joplin district increased Missouri's zinc output by 4,000,000 lbs., bringing it almost up to the production in 1907.

The opening of great porphyry deposits in the Ely district brought Nevada into fifth rank among copper producers with an increase of 350 per cent over the previous year.

The shut-down of the Homestake mines decreased the gold output of South Dakota by more than $1,000,000.

As in 1908 California led in oil production with Oklahoma second. Illinois continued in third place in spite of a slight drop in output.

Conservationists will note with some satisfaction the continued increase in the use of retort ovens in the coke industry.

A. D. B.

High School Geography, Physical, Economic and Regional; Pts. I and II, Physical and Economic. By CHARLES R. DRYER. American Book Co., 1911. Pp. 340.

The author of this new high-school text is already well known for his elementary textbook of physiography published eleven years ago and for many valuable papers upon Indiana geography. The present work is an attempt to combine an outline of commercial geography

with what is commonly included under physical geography and to adapt the book to a high-school course extending over a half-year. A supplementary volume is to be added for the use of schools which can devote more time to the subject.

The keynote of the book is the dependence of human life upon natural conditions. In the second part, which is entitled "Economic Geography," we find an excellent preparation for a study of conservation, the importance of which is now beginning to be realized. This section follows logically and naturally the physical geography, its four chapters being devoted to: natural resources and food supply; clothing and construction materials; heat, light, and power; and manufacture, trade, and transportation.

The book has an unusual number of maps, both in contour and in color; and its other illustrations, while particularly well chosen, are poorly reproduced. Specially interesting are the cloud photographs and the series chosen to illustrate plant regions. Geographical divisions used in descriptions are natural rather than political, which is a decided advantage.

W. H. H.

Rocks and Their Origin. By G. A. J. COLE. Cambridge University Series, 1912. Pp. vi+175.

There is always a danger that because of the special interest of the unusual and bizarre, the common objects in Nature's storehouse will be neglected. In this little manual Professor Cole has invested limestones, sandstones, and shales with interest while teaching important facts which are quite likely to be overlooked. Though written in an attractive style, the book's appeal will be strongest to the serious student of geology, for it is surprising how much has been compressed within its pages. The latter third is devoted to the igneous rocks and metamorphic rocks and treats of broad problems of origin and differentiation. The book is thoroughly up to date and concludes with a very valuable series of references each referred to by a number in the text.

W. H. H.

The Mining Districts of the Western United States. By JAMES M. HILL. Bull. No. 507, U.S. Geological Survey. Washington, 1912. Pp. 309; pls. 16.

A catalogue of the mining districts in the western part of the United States, using as a basis the map compiled by Lindgren in 1907. The districts are arranged by states, with subdivisions by counties. An alphabetical list is found in the index. In each district the location,

type of deposit, and metals produced are noted and a short bibliography of U.S. and state geological survey publications relating to the region is added.

A brief summary of the geology of the various states, by Lindgren, forms an introduction to the catalogue proper.

A. D. B.

The Data of Geochemistry. By F. W. CLARKE. Bull. No. 491, U.S. Geological Survey. Washington, 1911. Pp. 782.

A new edition of Bulletin No. 330, of the same title. A few revisions of minor importance are made to include new developments since the first edition.

A. D. B.

A CORRECTION

BERKELEY, CAL.
May 14, 1912

Editors "Journal of Geology":

DEAR SIRS: The January-February number of the *Journal of Geology* contains a paper by E. T. Dumble regarding some Tertiary and older deposits near Coalinga, Cal.

While in general he has given credit to the men whose work he has gleaned for his material, it is regrettable that some parts of the paper need correction. I have called his attention to this matter, but as nothing has been done I feel obliged to write to you myself.

On p. 32 there is a list of twenty-seven or more species the identification of which he has credited to me. I am compelled to state that his use of this list was premature and unauthorized, and it was not even contained in any of my private and confidential reports to him or to the Southern Pacific Company. I did indeed collect the fossils referred to, and had made a pencil list for purposes of study only, that was not designed for publication, as it needed confirmation or amendment. As it now stands it is incorrect in several of the identifications.

If Mr. Dumble had confided to me his desire to use this list, I would have furnished him one that was authentic and that would have been creditable to him and to myself, but as he did not, and as the matter stands, I do not wish to be sponsor for its accuracy.

F. M. ANDERSON

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